UNITED STATES PATENT AND TRADEMARK OFFICE
BEFORE THE BOARD OF PATENT APPEALS AND INTERFERENCES

In re Application of: Andre S. Chan et al.

Application Number: 10/788,953

Filed: February 26, 2004

For: DATA RECORDING DISK DRIVE WITH NONPLANAR PLATE SURFACES FOR DAMPING OUT-OF-PLANE DISK VIBRATION

Examiner: Watko, Julie Anne

Art Unit: 2627

SUPPLEMENTAL APPEAL BRIEF

This Supplemental Appeal Brief is submitted under 35 U.S.C. §134 and is further to Appellants' Appeal Brief filed March 1, 2007.

This Supplemental Appeal Brief is in response to the Examiner's telephone call of May 3, 2007, in which the Examiner stated that the Evidence Appendix, as described in 37 CFR §41.37(c)(1)(ix), requires submission of copies of the references cited by the Examiner during prosecution to reject the claims on appeal, together with a statement stating where in the record those references were entered by the Examiner.

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(1) Real Party in Interest

The real party in interest is Hitachi Global Storage Technologies, Inc.

(2) Related Appeals and Interferences

No other appeals or interferences exist that relate to the present application or appeal.

(3) Status of Claims

Claims 1-5, 10 and 12 are being appealed.

Claims 1-3 stand rejected under 35 U.S.C. 102(e) as being anticipated by Butt et al. (U.S. Patent No. 7,031,104 B1), hereafter referred to as "Butt."

Claims 4-5, 10 and 12 stand rejected under 35 U.S.C. 103(a) as being unpatentable over Butt in view of Machcha et al. (U.S. Patent No. 6,882,501 B2), hereafter referred to as "Machcha."

(4) Status of Amendments

An Amendment after Final Rejection was filed 10/20/2006 and was entered in an Advisory Action dated 10/27/2006. No amendments are outstanding.

(5) Summary of Claimed Subject Matter

Problem addressed by the invention

The invention relates to magnetic recording hard disk drives, and more specifically to disk drives that use damping plates near the rotating disks to reduce vibration. As the disks rotate at high speed (e.g., up to 15,000 RPM), the recording heads, which are supported by arm/suspension assemblies, are moved across the disk surfaces. Air-flow turbulence induced by the rotating disks near the outer perimeter of the disks causes vibration of the arm/suspension assemblies and the attached recording heads and out-of-plane vibration (often

called “flutter”) of the disks. These vibrations can cause recording head positioning errors and thus errors in reading data from and writing data to the disks.

Disk vibration damping plates are known to address this problem. These damping plates have planar surfaces parallel to the planar surfaces of the disks and extend between the disks near their outer perimeters to encourage laminar air flow and thus a reduction in turbulence. However, these damping plates also cause high viscous shear forces on the disks, which require a higher spindle-motor torque, and thus higher power consumption, to maintain the desired high rotational speed of the disks.

This invention addresses the problem of reducing the viscous shear forces caused by damping plates without losing the benefit of reduced air-flow turbulence.

Summary of the subject matter of independent claim 1

The subject matter of independent claim 1 is a disk drive that includes a housing (12, 14 in Fig. 3), at least one rotatable disk (for example, disk 64 in Fig. 3), and a damping plate (44 in Fig. 3; 300 in Fig. 6A) fixed to the housing and extending circumferentially around a sector of the disk and radially across a radially outer annular region of the disk. The damping plate has a substantially planar surface (82 in Fig. 3; 302 in Fig. 6A) that faces a disk surface (92 in Fig. 3). The inventive feature, which addresses the problem of high viscous shear forces, is that the planar surface (302 in Fig. 6A) of the damping plate (300 in Fig. 6A) has discrete surface features (306 in Fig. 6A) that are arranged in a pattern of radially-spaced concentric rings, with the surface features in each ring being circumferentially spaced-apart. The arrangement of the discrete surface features in rings results in rings of substantially planar surfaces between the rings of surface features, which reduces the turbulent intensity (page 7, lines 17-20).

Summary of the subject matter of independent claim 4

The subject matter of independent claim 4 is a disk drive like that described above for independent claim 1 with the additional features being that the disk drive includes a stack of disks (62, 64, 66 in Fig. 3) and that the damping plate (44 in Fig. 3) is located between two axially adjacent disks (62, 64 in Fig. 3) in the disk stack. The damping plate has two planar surfaces, each with a pattern of surface features like that described above for independent

claim 1, with each planar surface facing a disk surface of one of the two axially-adjacent disks.

(6) Grounds of Rejection to be Reviewed on Appeal

Appellant respectfully traverses the following grounds of rejection and requests that they be reviewed on appeal:

Claims 1-3 stand rejected under 35 U.S.C. 102(e) as being anticipated by Butt.

Claims 4-5, 10 and 12 stand rejected under 35 U.S.C. 103(a) as being unpatentable over Butt in view of Machcha.

(7) Arguments

(a) The rejection of Claim 1 under Section 102(e) as being anticipated by Butt is in error because an element of Appellants' invention is not disclosed in Butt.

Anticipation under 35 USC §102 requires strict identity between the prior art reference and the claim, i.e., the prior art reference must disclose, either expressly or inherently, all of the elements and limitations of the claim. *Rapoport v. Dement*, 254 F.3d 1053, 1057, 59 USPQ2d 1215 (Fed. Cir. 2001) is but one example of numerous citations stating this well-established rule.

The element of Claim 1 not disclosed by Butt is the following:

> "each ring comprising a plurality of circumferentially spaced-apart surface features"

The "circumferentially spaced-apart surface features" in "each ring" are items 306 in Figs. 6A-6B.

The erroneous application of Butt is reprinted below from the Advisory Action, wherein the bold-italicized portion is the objectionable interpretation:

> Butt et al explicitly teach "channels 204 concentrated in one or more portions of an inner surface of the base" (see col. 8, lines 20-21). Butt et al further teach "channels 204 concentrated in one or more portions of the inner surface of the base 180" (see col. 8, lines 60-64). ***It is clear that such "portions" are circumferentially spaced apart portions, insofar as Butt et al show that a "plurality of arcuate channels 158 are located upstream of the actuator arm 50" (see col. 7, lines 32-33), that "channels 158 are located downstream of the actuator arm 50" (see col. 7, lines 33-34), and that "channels 158 are located roughly midway between the upstream side of the actuator arm 50 and the downstream side of the actuator arm 50" (see col. 7,***

> ***lines 35-37).*** The Examiner believes that these teachings together would fairly result in anticipation of the new limitation in independent claim 1. *(emphasis added)*

The above-quoted basis for the assertion that Butt teaches the "circumferentially spaced-apart surface features" is in clear violation of the "strict identity" test for anticipation. Strict identity means not merely that every element and limitation of the claim can be found in a single prior art reference, but that those elements in the prior art reference are "arranged as in the claim". *Brown v. 3M,* 265 F.3d 1349, 1351, 60 USPQ2d 1375 (Fed. Cir. 2001). In this case the examiner has picked an element from three independent and alternative embodiments disclosed in Butt and combined them to arrive at the claimed element.

The above bold-italicized portion from the Advisory Action refers to "channels 158", which are shown in Fig. 5D of Butt. The objectionable interpretation of Butt is that channels 158 are located in three discrete circumferential locations, thereby apparently reading on Appellants' "discrete circumferentially spaced-apart surface features". However, Butt teaches that these are three distinct alternative embodiments. In col. 7, lines 29-37, Butt states:

> In ***one embodiment***, the plurality of arcuate channels 158 are on the cover 150 so that when the cover 150 is affixed to the base 30, the plurality of arcuate channels 158 are located upstream of the actuator arm 50. ***In other embodiments***, the channels 158 are located downstream of the actuator arm 50. ***In another embodiment***, the channels 158 are located roughly midway between the upstream side of the actuator arm 50 and the downstream side of the actuator arm 50. *(emphasis added)*

The bold-italicized portions in the immediately-above quotation were conveniently omitted from the quotation of Butt that appears in the Advisory Action. Thus the rejection is based on selecting a single feature from three distinct alternative embodiments of Butt and combining those features. These three separate elements of Butt are clearly *not* "arranged as in the claim". *Brown v. 3M, supra.*

The Examiner has thus engaged in "picking, choosing, and combining various disclosures not directly related to each other", a technique like that which was deemed improper in *In re Arkley,* 455 F.2d 586, 172 USPQ 524 (CCPA 1972). In that case the Patent Office combined (1) a specific example of a C-type precursor of the claimed compound, (2) a general teaching of how to convert cephalosporin C-type into cephalosporin C_A-type, and (3) a general statement that compounds with the C_A nucleus have better antibacterial effect than

those with the C nucleus. The CCPA held this to be improper and stated the general rule as follows:

> Thus, for the instant rejection under 35 U.S.C. § 102(e) to have been proper, the Flynn reference must clearly and unequivocally disclose the claimed compound or direct those skilled in the art to the compound without *any* need for picking, choosing, and combining various disclosures not directly related to each other by the teachings of the cited reference. Such picking and choosing may be entirely proper in the making of a 103, obviousness rejection, where the applicant must be afforded an opportunity to re-but with objective evidence any inference of obviousness which may arise from the *similarity* of the subject matter which he claims to the prior art, but it has no place in the making of a 102 anticipation rejection. *In re Arkley, supra* at 587.

More importantly, even if the examiner's combination of these three alternative embodiments were proper, the basis for the combination is made on an erroneous interpretation of Butt. This erroneous interpretation is the following statement in the Advisory Action:

> Butt et al explicitly teach "channels 204 concentrated in ***one or more portions*** of an inner surface of the base" (see col. 8, lines 20-21). Butt et al further teach "channels 204 concentrated in ***one or more portions*** of the inner surface of the base 180" (see col. 8, lines 60-64). ***It is clear that such "portions" are circumferentially spaced apart portions*** … *(emphasis added)*

It is clear that the "one or more portions" referred to in Butt are *not* "circumferentially spaced-apart portions." Rather, they are *radially* spaced-apart portions. The quoted language from Butt (col. 8, lines 20-21) refers to Fig. 5A. Fig. 5A has an "outer portion 94" and a "middle portion 98" (col. 5, line 63 to col. 6, line 7). These are clearly *radial* portions. Thus, the assertion that Butt teaches one or more "circumferentially spaced-apart portions" , which is the basis for the combination of the three alternative embodiments, is clearly erroneous.

(b) <u>The rejection of Claim 1 under Section 102(e) as being a "mere relocation of parts" is not supported by Butt and is based on the examiner's erroneous interpretation of Butt.</u>

The Section 102(e) rejection in the Advisory Action further states:

> However, even if these teachings together did not result in anticipation of independent claim 1, there would be no invention in relocating known parts, when the operation of the apparatus were not modified by the relocation. *In re Japikse,* 181 F.2d 1019, 86 USPQ 70 (CCPA 1950).

This maxim is not applicable here. The "parts" of Butt are radially-spaced continuous arcuate channels. There is no teaching in Butt that a continuous arcuate channel can be a plurality of circumferentially-spaced channels. Just where did Appellants relocate these "parts"? It is clear that there is no mere relocation of these arcuate channels because Appellants' "parts" are rings, with each ring being "discrete circumferentially spaced-apart surface features". The maxim can only be applied by relying on the above-described erroneous interpretation of Butt, namely that the "one or more portions" of Butt are circumferentially spaced-apart portions.

(c) <u>The rejection of Claim 4 under Section 103(a) over Butt in view of Machcha fails to state a *prima facie* case of obviousness.</u>

As explained in the preceding sections, Butt does not teach that for which it is asserted and thus fails as a primary reference. Thus a *prima facie* case of obviousness has not been established.

For the reasons stated above, all the claims presently on file in the present application are in condition for allowance, and such action is respectfully requested.

Respectfully submitted,

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APPENDIX A
CLAIMS APPENDIX

1. A data recording disk drive comprising:

a housing;

at least one disk rotatable about an axis of rotation;

a motor attached to the housing for rotating the disk;

a plate fixed to the housing, the plate extending circumferentially around a sector of the disk and radially across a radially outer annular region of the disk, the plate having a substantially planar surface facing a disk surface, said plate surface having a plurality of discrete surface features arranged in a pattern of radially-spaced concentric rings, each ring comprising a plurality of discrete circumferentially spaced-apart surface features.

2. The disk drive of claim 1 wherein there is only one disk, wherein the housing includes a base, the motor and disk being mounted on the base, and wherein the plate is part of the base and said plate surface faces the bottom surface of the disk.

3. The disk drive of claim 1 wherein there is only one disk, wherein the housing includes a base, the motor and disk being mounted on the base, and wherein the plate is part of the cover and said plate surface faces the top surface of the disk.

4. A data recording disk drive comprising:

a housing;

a rotatable stack of disks axially spaced along a common axis of rotation;

a motor attached to the housing for rotating the disk stack;

a plate fixed to the housing and located between two axially adjacent disks, the plate extending circumferentially around a sector of the two disks and radially across a radially outer annular region of the two disks, the plate having a substantially planar first surface facing a surface of a first disk and a substantially planar second surface facing a surface of the second disk, said first and second plate surfaces each having a plurality of discrete surface features arranged in a pattern of radially-spaced concentric rings, each ring comprising a plurality of discrete circumferentially spaced-apart surface features.

5. The disk drive of claim 4 further comprising a plurality of plates, each plate being located between a different set of two axially adjacent disks.

10. The disk drive of claim 4 wherein the surface features are dimples.

12. The disk drive of claim 4 wherein the surface features are bumps.

APPENDIX B

EVIDENCE

1. U.S. Patent No. 7,031,104 B1, referred to herein as "Butt." Butt was entered into the record by the Examiner in the Office communication mailed 07/27/2006 at paragraph 3.

US007031104B1

(12) United States Patent
Butt et al.

(10) Patent No.: US 7,031,104 B1
(45) Date of Patent: Apr. 18, 2006

(54) **DISK DRIVE HAVING GUIDE-VANES**

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(73) Assignee: **Western Digital Technologies, Inc.**, Lake Forest, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 355 days.

(21) Appl. No.: **10/137,481**

(22) Filed: **Apr. 30, 2002**

(51) **Int. Cl.**
G11B 33/14 (2006.01)
G11B 5/54 (2006.01)

(52) **U.S. Cl.** **360/97.02**; 720/649

(58) **Field of Classification Search** 360/97.02, 360/97.03; 369/247, 263, 247.1, 263.1; 720/648–649, 720/651–652

See application file for complete search history.

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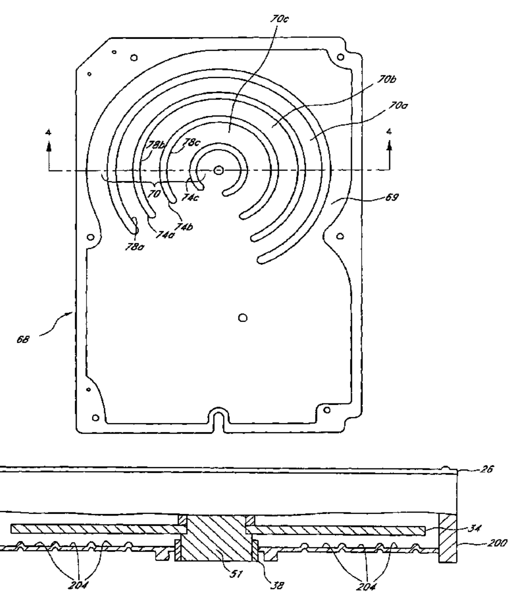
Primary Examiner—Brian E. Miller
(74) *Attorney, Agent, or Firm*—Knobbe Martens Olson & Bear; Joshua C. Harrison, Esq.

(57) **ABSTRACT**

A disk drive includes an enclosure, a rotatable disk and an actuator arm, and also includes a plurality of arcuate channels. Airflow is created within the enclosure when the disk rotates. The plurality of arcuate channels facing the disk to decrease the turbulence of the airflow with respect to the actuator arm. The arcuate channels are formed on at least one portion of the enclosure.

10 Claims, 11 Drawing Sheets



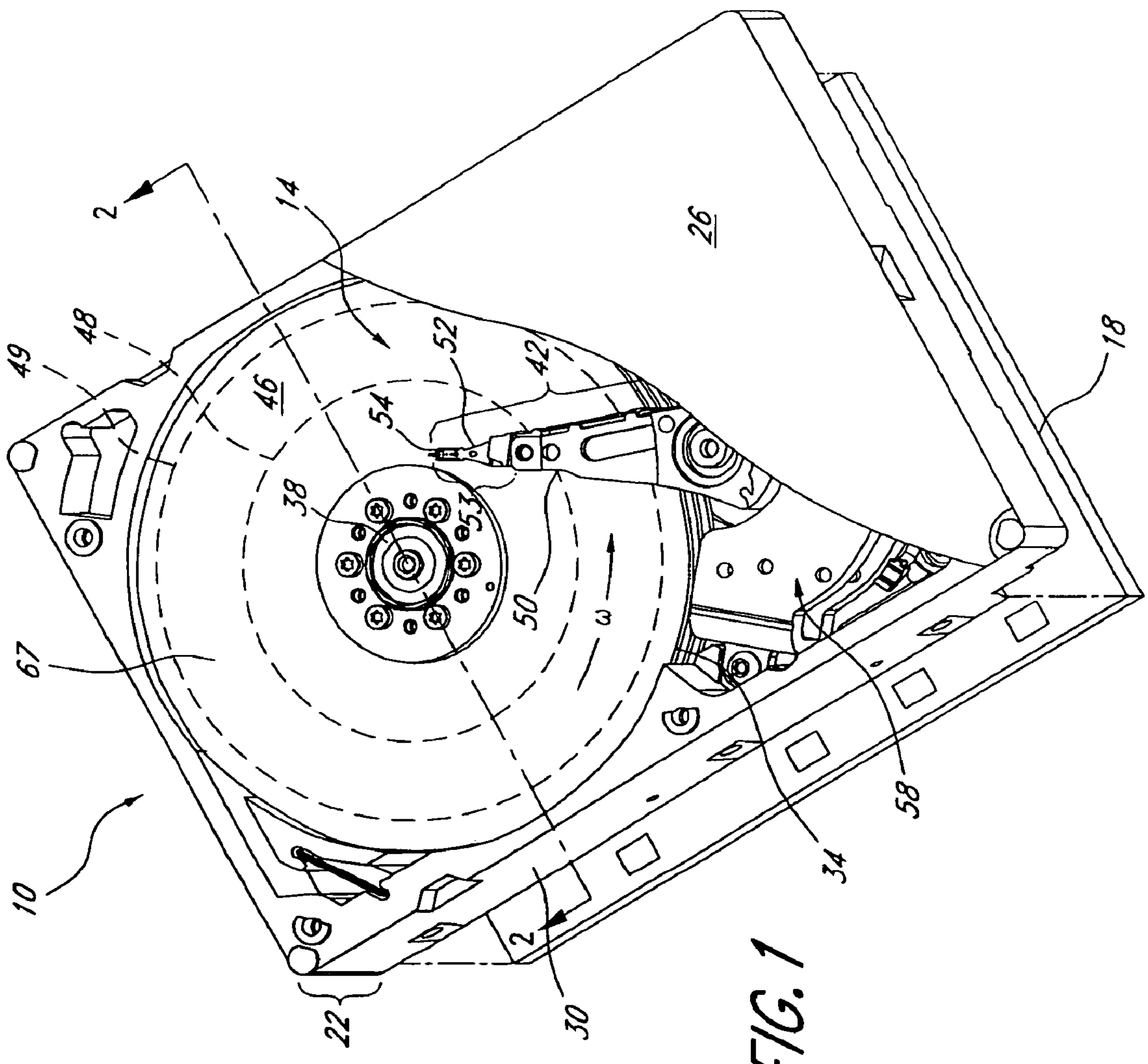


FIG. 1

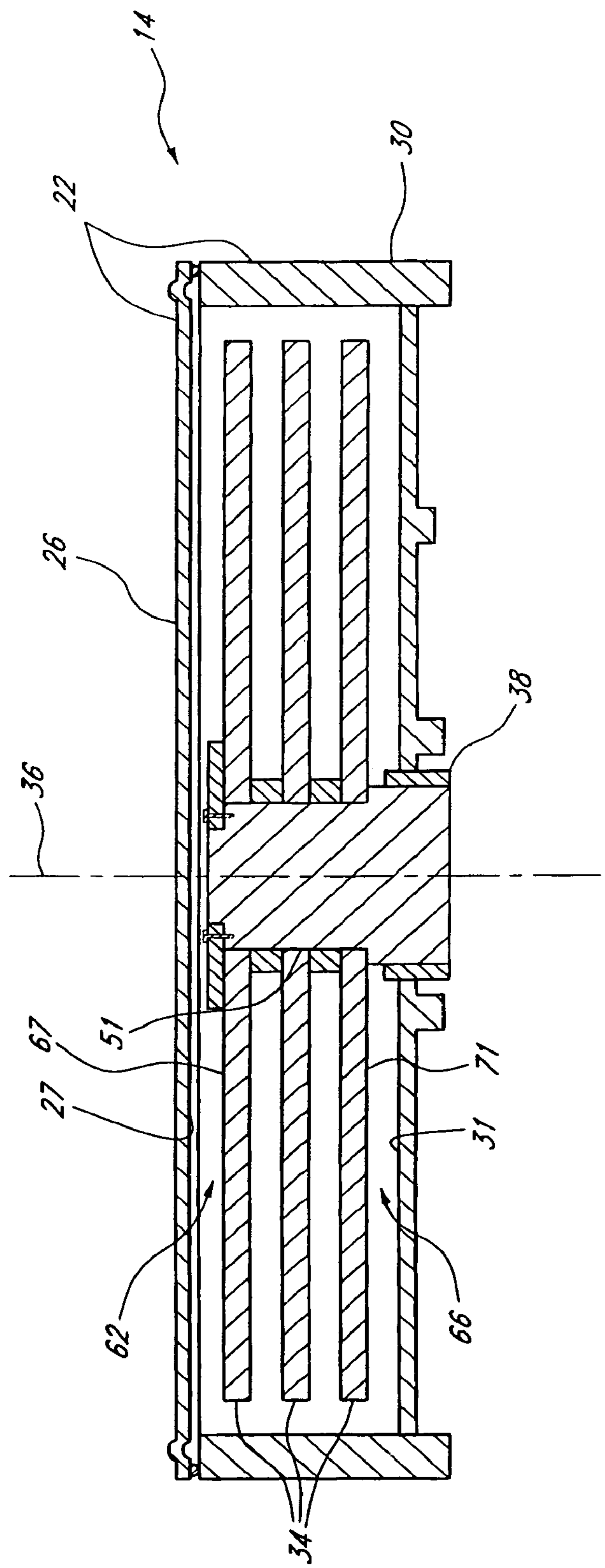


FIG. 2

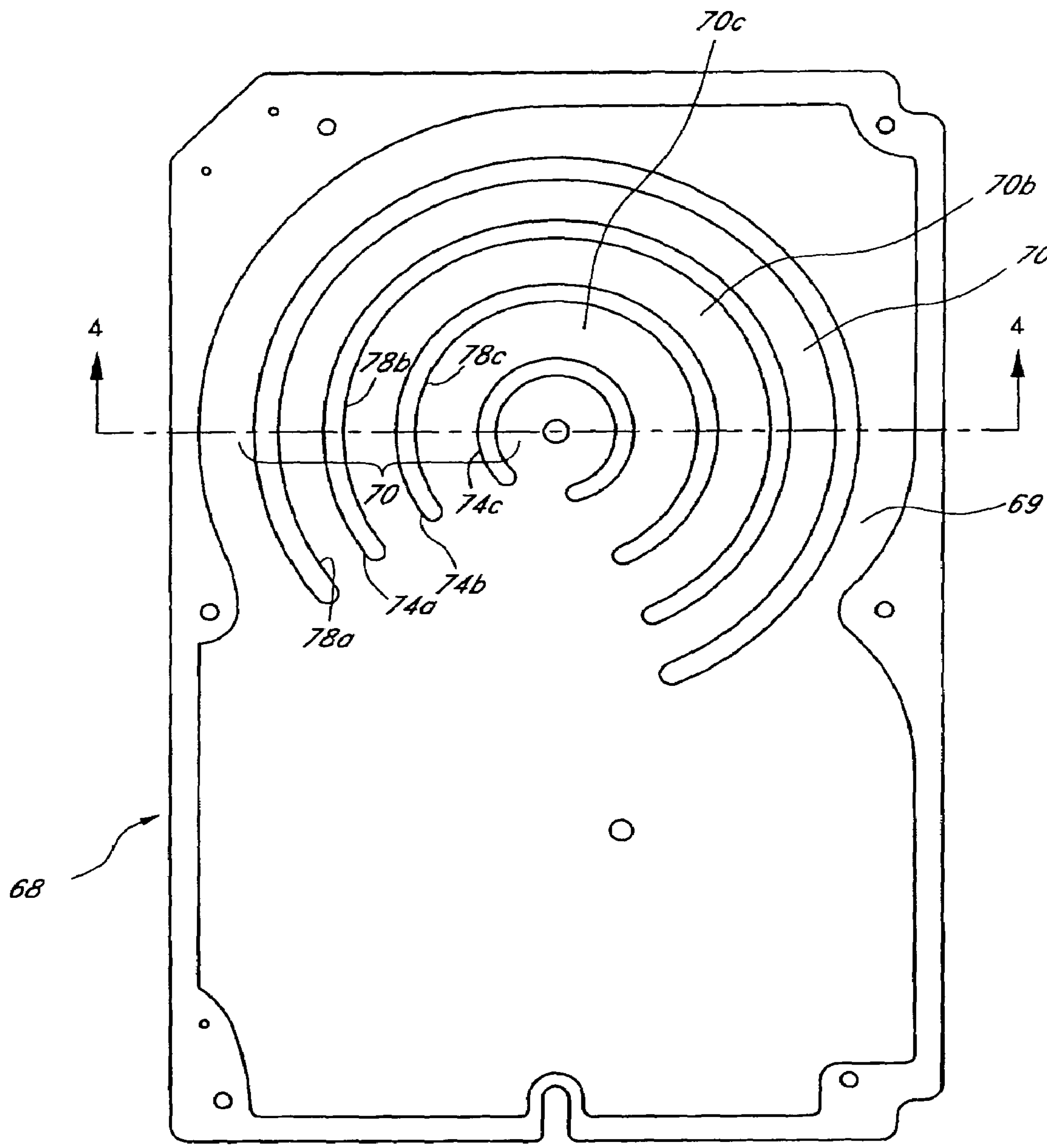


FIG. 3

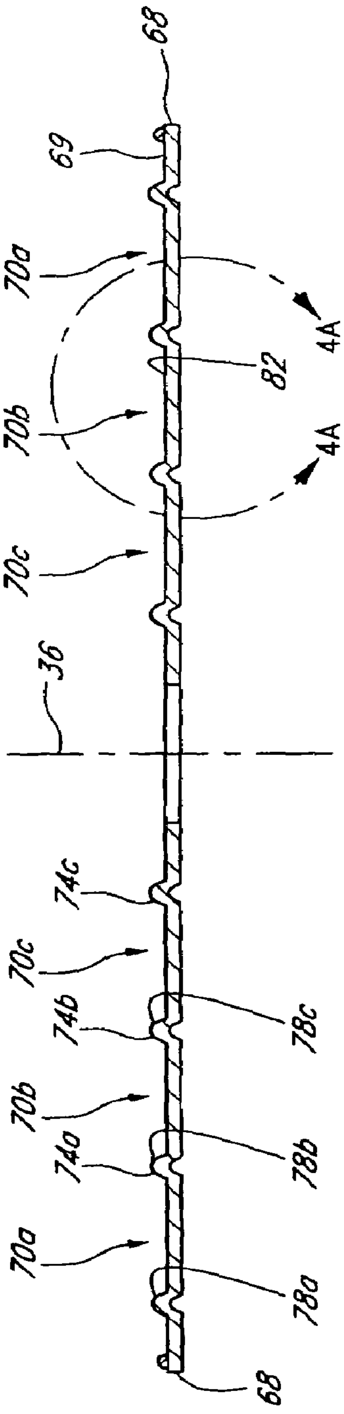


FIG. 4

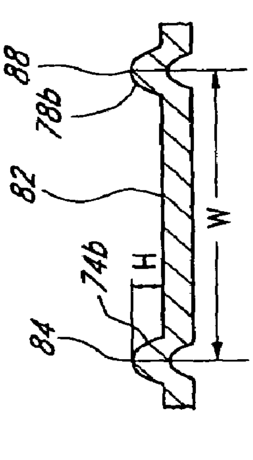


FIG. 4A

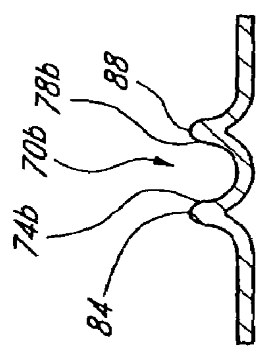


FIG. 4B

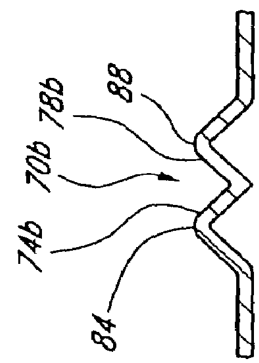


FIG. 4C

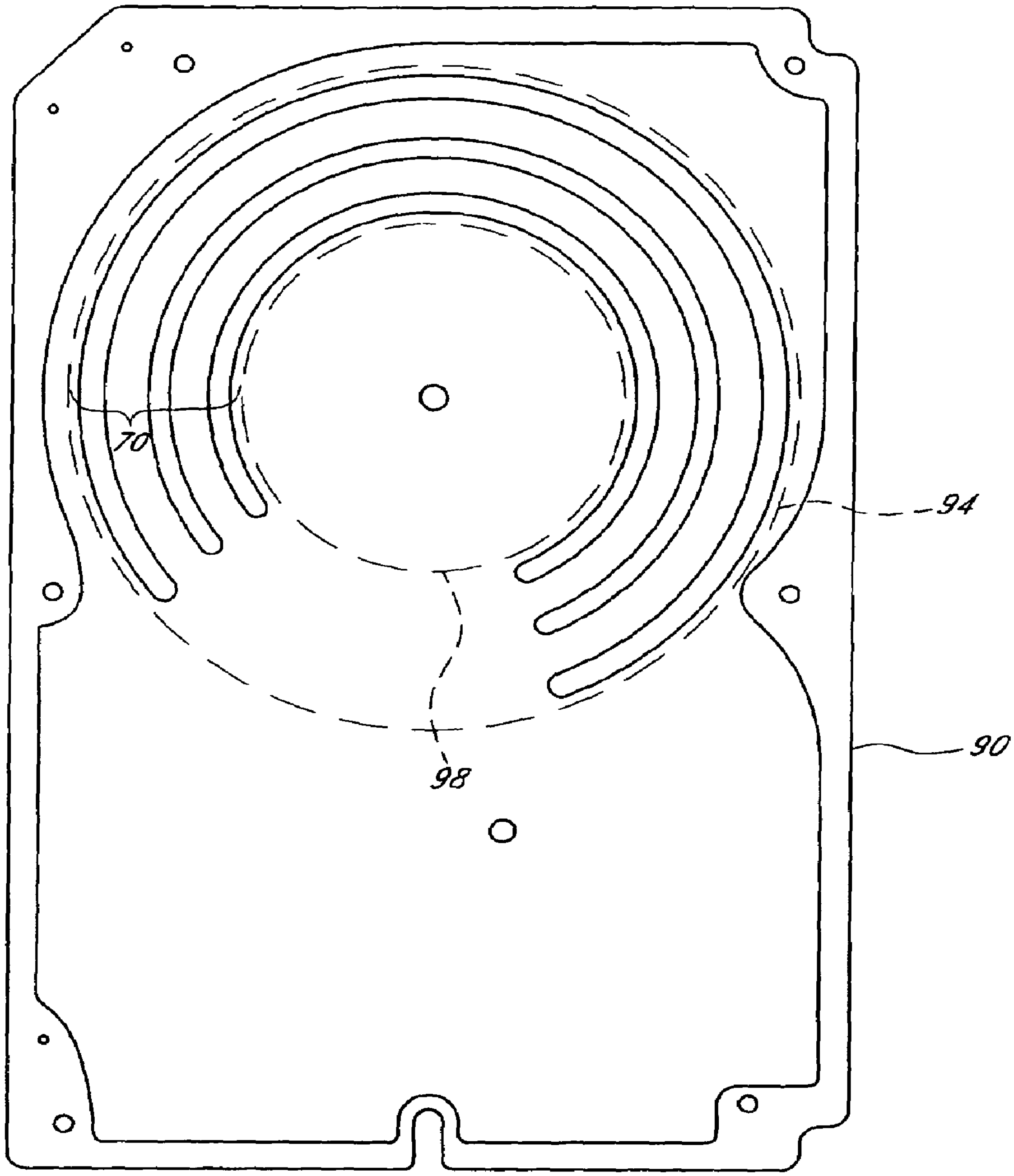


FIG. 5A

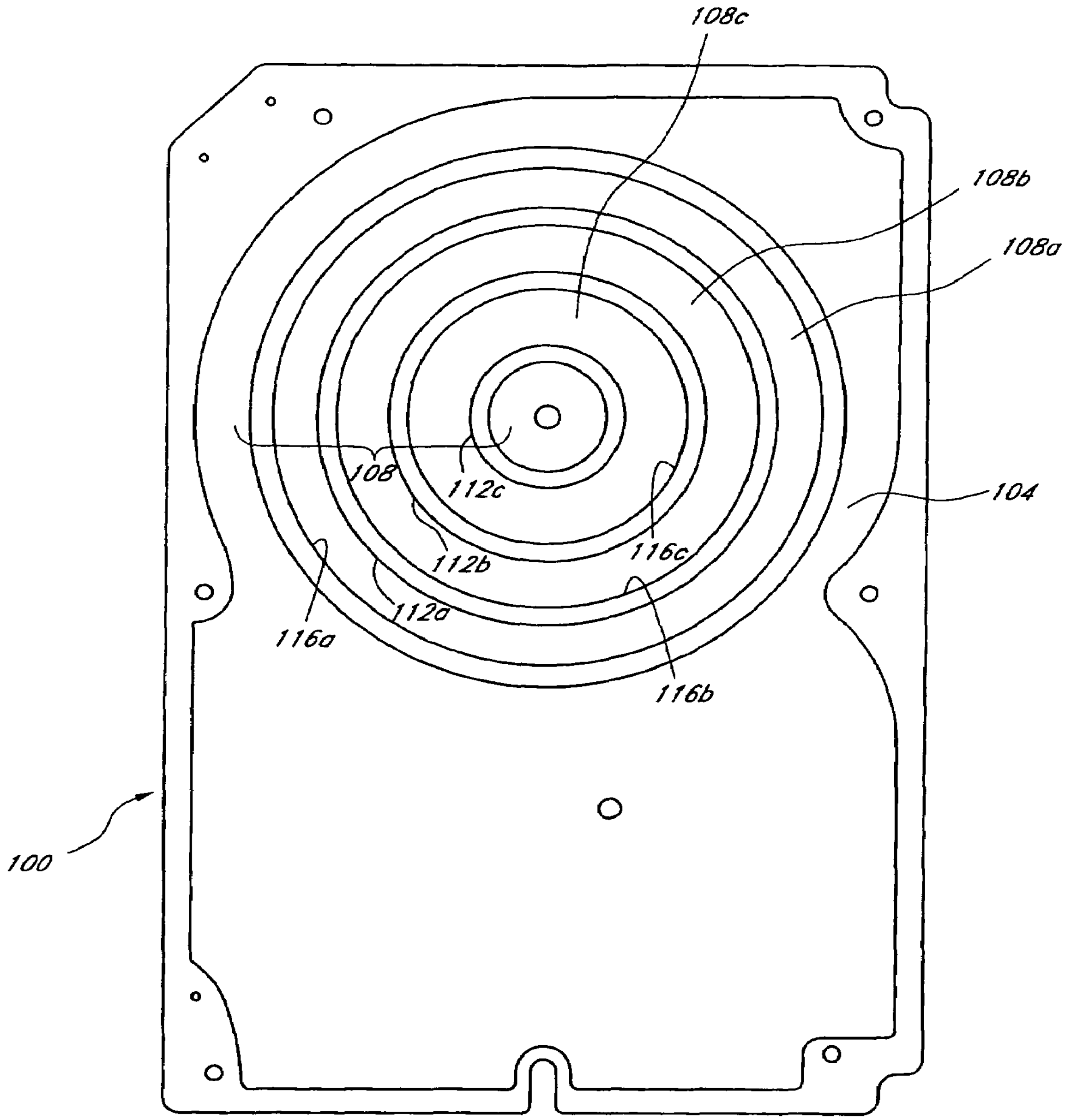
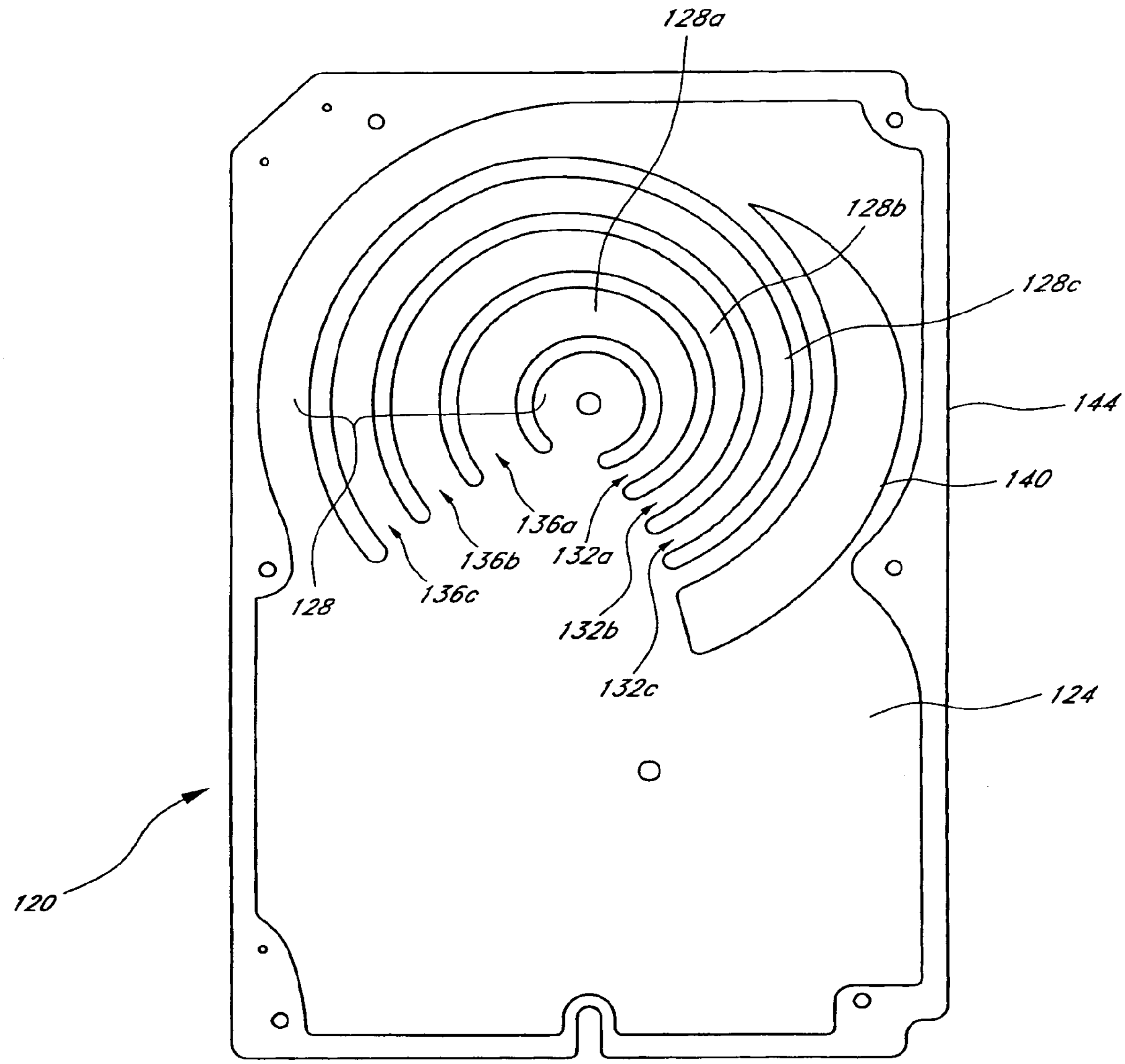


FIG. 5B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136c
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132b
132c
124
120

FIG. 5C

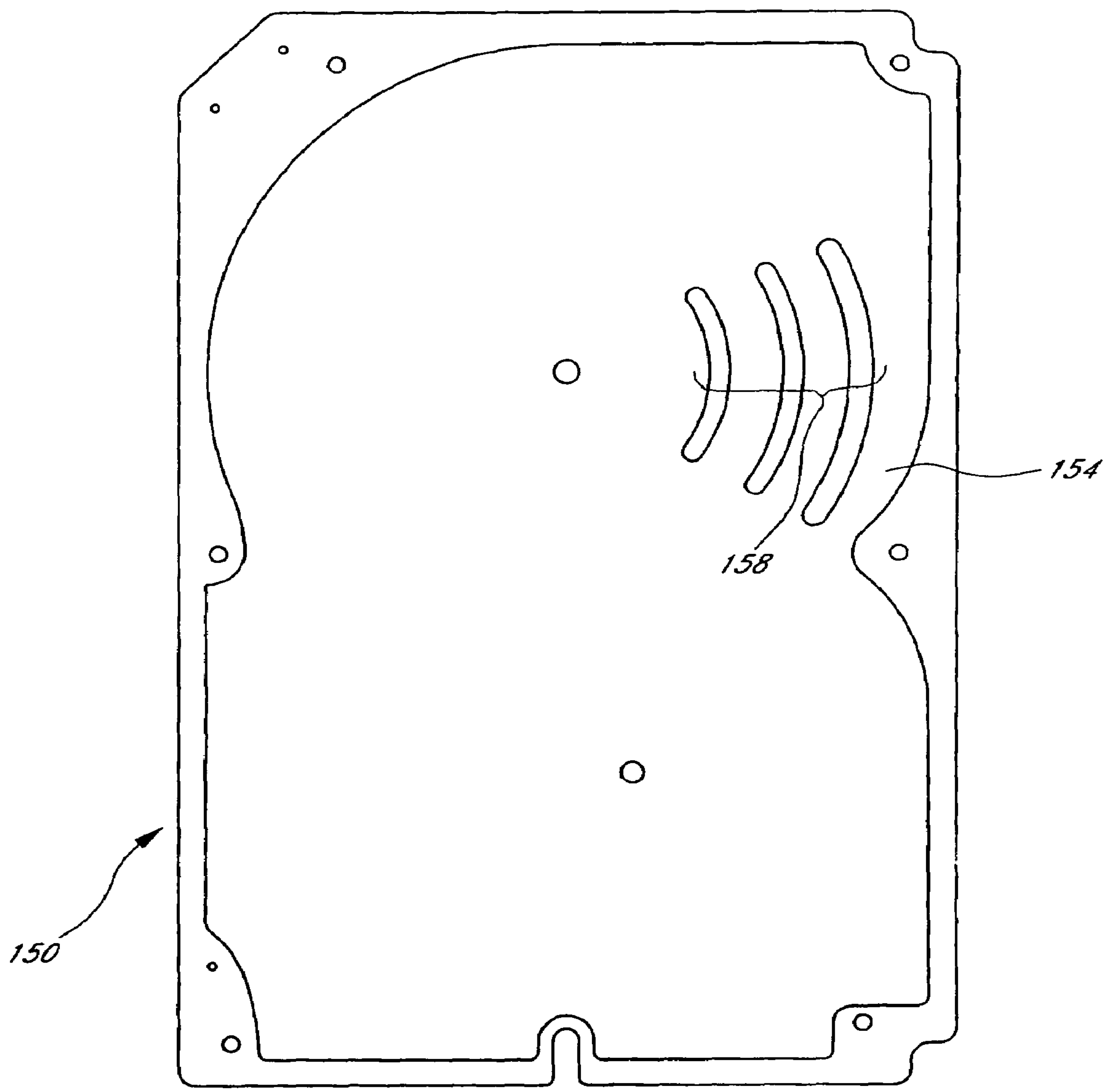

FIG. 5D

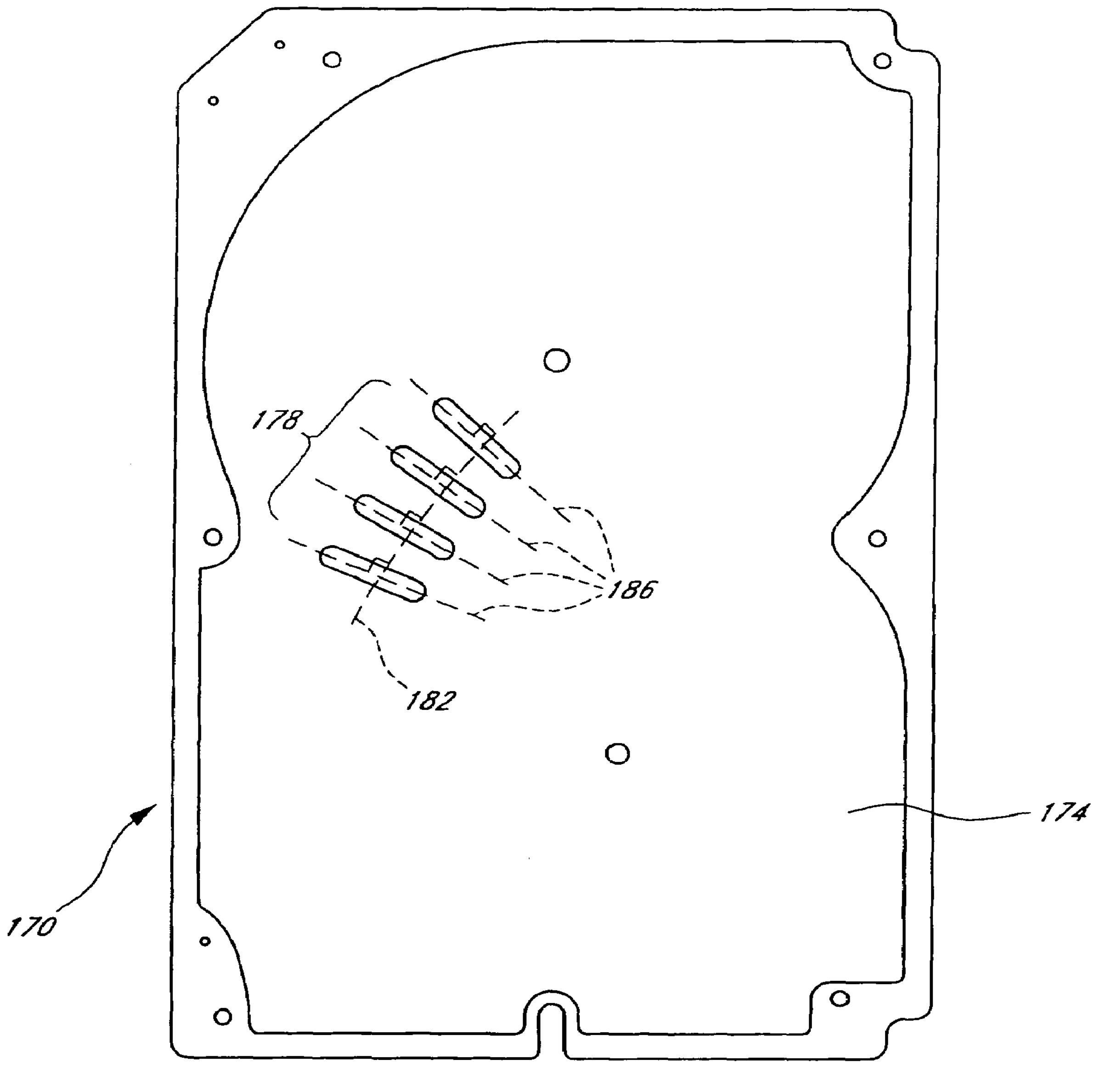

FIG. 5E

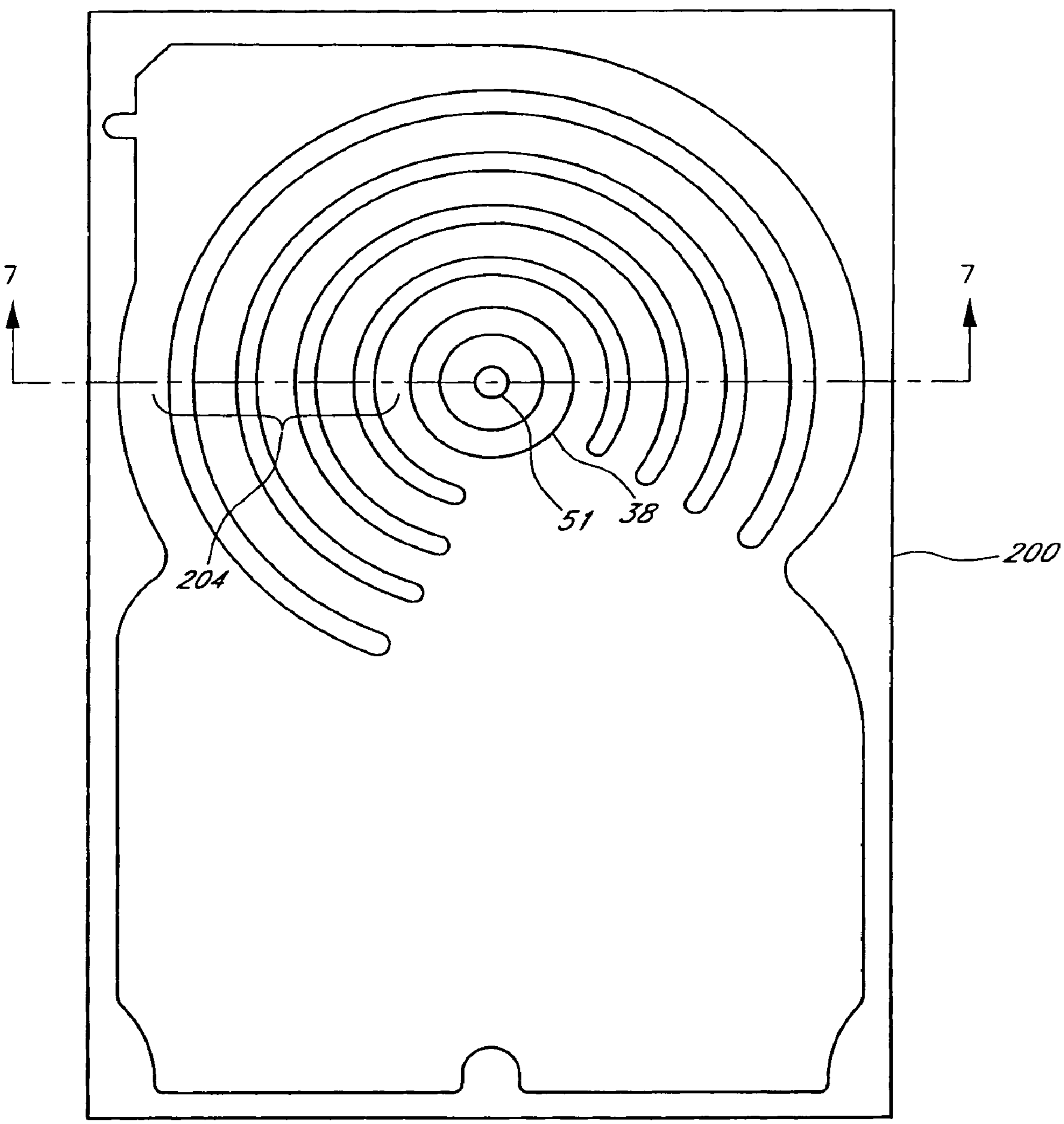

FIG. 6

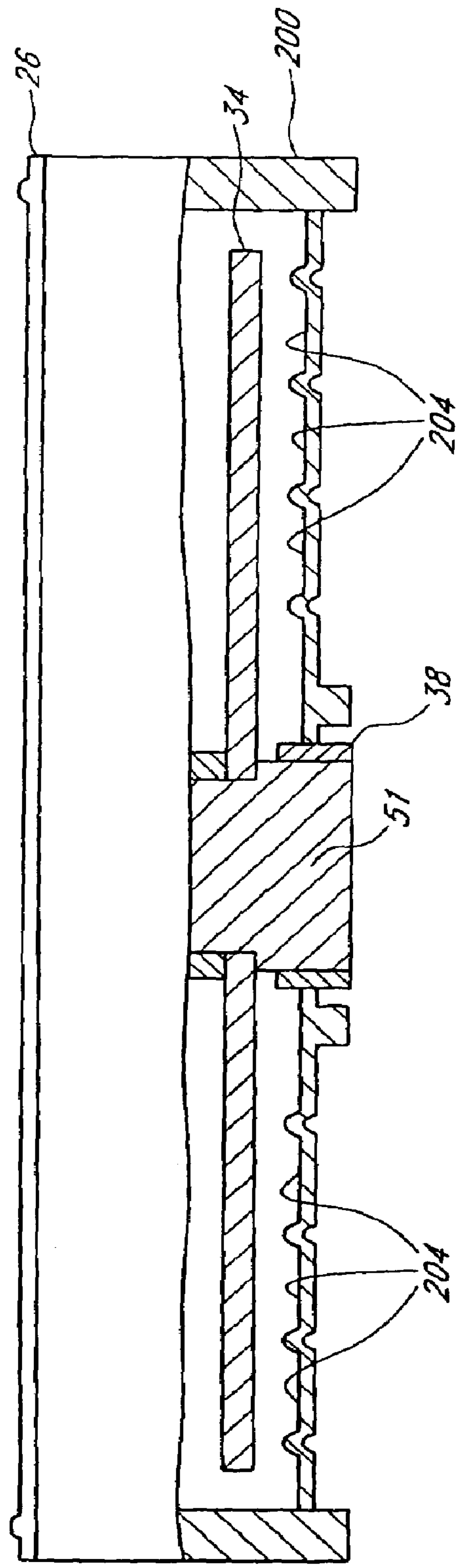

FIG. 7

DISK DRIVE HAVING GUIDE-VANES

BACKGROUND OF THE INVENTION

1. Field of the Invention

This application relates to a disk drive and more particularly relates to the construction of the components that enclose the disks within the disk drive.

2. Description of the Related Art

One type of data storage device used in a computer to permanently store data is a disk drive. A disk drive includes at least one disk with a magnetic medium that is mounted on and rotated by a spindle motor. The disk drive also includes a data transfer head that writes data onto the magnetic medium and that reads data from the medium in concentric, generally circular tracks. In most applications, the data transfer head is extended out over the magnetic medium by an actuator assembly that moves the head in an arcuate path with respect to the medium. The tracks on the disk are divided into sectors, which are presented to the data transfer head by the rotation of the disk. An enclosure surrounds these components of the disk drive.

The servo-system includes servo data written onto the tracks that can be read by the data transfer head to give an indication of how close the head is to the centerline of a track. When the head is over the centerline of the track and follows it, the head is said to be track-following. When the head wanders from the centerline of the track, there is said to be track misregistration, or "TMR."

Several factors influence the TMR that the disk drive will experience. For example, rotation of the disk causes airflow in the disk drive enclosure. This airflow impinges upon the disk drive components and causes vibrations in those components. For example, under certain circumstances, airflow within the enclosure causes the disks to vibrate. These vibrations cause relative motion between the tracks on the disks and the head, which increases TMR. Increased TMR is not desirable because increased TMR limits track-to-track spacing (i.e., track pitch) and consequently limits areal density.

SUMMARY OF THE INVENTION

It is an object of this invention to decrease turbulent flow of air in the space between a surface of a rotating disk and a surface of a portion of an enclosure that is stationary with respect to the disk.

In one embodiment, the present invention comprises a disk drive that includes an enclosure, a disk, an actuator arm, and a plurality of arcuate channels. The enclosure includes a base and a cover. The disk is rotatable about an axis within the enclosure. The rotating disk creates airflow within the enclosure. The disk has a magnetic medium formed on at least one surface thereof. The actuator arm positions a data transfer head proximate the surface of the disk. The plurality of arcuate channels are located on the enclosure facing the at least one surface of the disk to decrease the turbulence of the airflow with respect to the actuator arm.

In another embodiment, the present invention is a disk drive that has an enclosure, a disk that rotates about an axis within the enclosure, and an actuator arm. The enclosure includes a base and a cover. The disk has a magnetic medium formed on at least one surface thereof. The rotating disk creates airflow within the enclosure. The actuator arm positions a data transfer head proximate the surface of the disk. The disk drive also includes means for reducing the turbulence of the airflow to decrease the TMR of the disk drive. The means is located on the enclosure facing the at least one surface of the disk.

In another embodiment, the present invention comprises a disk drive that includes an enclosure, a disk and an actuator arm. The enclosure includes a base and a cover. The disk is rotatable about an axis within the enclosure. The rotating disk creating airflow within the enclosure. The disk has a magnetic medium formed on at least one surface thereof. The actuator arm positions a data transfer head proximate the surface of the disk. The data transfer head traces out a path over the at least one surface of the disk. The disk drive also has a plurality of channels located on the enclosure facing the at least one surface of the disk. Each of the channels has a longitudinal axis that is perpendicular to the path traced out by the data transfer head.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings are included to provide a further understanding of the present invention and are incorporated in and constitute a part of this specification. The drawings illustrate embodiments of the present invention and together with the description serve to explain the principles of the invention.

FIG. **1** is a perspective view of one embodiment of a disk drive with a printed circuit board removed and a cover partially broken away to illustrate internal components.

FIG. **2** cross-section view of a head-disk assembly of the disk drive of FIG. **1** taken along a section line **2**—**2**.

FIG. **3** is a bottom plan view of one embodiment of a cover of a disk drive.

FIG. **4** is a cross-sectional view of the disk drive cover of FIG. **3** taken along a section line **4**—**4**.

FIG. **4**A is an enlarged sectional view of a portion of the cover of FIGS. **3** and **4** taken along the section line **4**A—**4**A.

FIG. **4**B is an enlarged sectional view of a portion of another embodiment of a cover having a transverse cross-section that includes a semi-circular portion.

FIG. **4**C is an enlarged sectional view of a portion of another embodiment of a cover having a transverse cross-section that includes a substantially "V-shaped" profile.

FIG. **5**A is a bottom plan view of another embodiment of a cover of a disk drive.

FIG. **5**B is a bottom plan view of another embodiment of a cover of a disk drive.

FIG. **5**C is a bottom plan view of another embodiment of a cover of a disk drive.

FIG. **5**D is a bottom plan view of another embodiment of a cover of a disk drive.

FIG. **5**E is a bottom plan view of another embodiment of a cover of a disk drive.

FIG. **6** is a top view of a base of a disk drive.

FIG. **7** is an elevation view in partial cross-section of a disk drive including the disk drive base of FIG. **6** with a portion of the base broken away to show the relationship of the spindle motor hub, a disk mounted thereon, and the disk drive base.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. **1** is a perspective view of a disk drive **10**. The disk drive **10** includes a head-disk assembly (HDA) **14** and a printed circuit board **18**. The HDA **14** comprises an enclosure **22** that includes a cover **26** and a base **30**. The cover **26** has an inner surface **27** that faces the internal components of

the disk drive **10** when the disk drive **10** is assembled. The base **30** has an inner surface **31** that faces the internal components of the disk drive **10** when the disk drive **10** is assembled. The printed circuit board **18** is connectable to the base **30**, but is shown removed therefrom in FIG. **1** for illustration. The HDA **14** also includes at least one disk **34**, a spindle motor assembly **38**, and a head-stack assembly (HSA) **42**. In the illustrated embodiment, the disk drive **10** includes three disks **34**. The disks **34** are rotatable within the enclosure **22** about an axis **36**. Each disk **34** is mounted on the spindle motor assembly **38**. One skilled in the art will recognize that the disk drive claimed herein includes more or fewer disks **34** in other embodiments.

Each disk **34** has at least one surface **46** that has a magnetic medium deposited thereon. Magnetic transitions representing data are written onto and read from the magnetic medium in a known manner. Each of the disks **34** has a middle circumference **48** and an outer circumference **49**. The outer circumference **49** is located proximate the outer edge of the disk **34**. The middle circumference **48** is located between the outer circumference **49** and the inner edge of the disk **34**. The middle circumference **48** need not be one-half the distance between the outer circumference **49** and the inner edge of the disk **34**. The magnetic medium extends at least between the middle circumference **48** and the outer circumference **49**.

The HSA **42** includes an actuator arm **50** that positions a data transfer head **54** proximate each of the surfaces **46** that are included in the disk drive **10**. One skilled in the art will recognize that a head-gimbal assembly **53** is provided that comprises the data transfer head **54** and a suspension assembly **52**. One end of the suspension assembly **52** of the head-gimbal assembly **53** is mounted on the actuator arm **50**. The data transfer head **54** includes, in one embodiment, a read element and a write element and thus operates in a read/write system. One skilled in the art will recognize that the invention claimed below could also be used to reduce TMR in a read-only application, i.e., in an application having a data transfer head with a read element only.

The actuator arm **50** is positioned by a rotary actuator **58** that is positioned under the control of a conventional servo system.

The spindle motor assembly **38** includes a rotatable hub **51** to which the disks **34** are mounted. The spindle motor assembly **38** is electrically connected to circuitry located on the printed circuit board **18**, e.g., to a spindle motor controller. The spindle motor controller controls the rotation of the hub **51** of the spindle motor assembly **38** and the disks **34** attached thereto. When the disk drive **10** is operating, the disks **34** are rotated at a substantially constant angular velocity (o. The direction of the rotation of the disks **34** is indicated in FIG. **1**. Of course, one skilled in the art will recognize that the invention described herein can be carried out in a disk drive having rotation opposite of that shown in FIG. **1**.

The rotation of the disks **34** creates airflow within the enclosure **22**. In particular, airflow is created in a first enclosure space **62** and in a second enclosure space **66**. FIG. **2** illustrates that the first enclosure space **62** is defined by the inner surface **27** of the cover **26** and an upper surface **67** of the uppermost disk **34** that is mounted on the spindle motor assembly **38** farthest from the printed circuit board **18** (see FIG. **1**). FIG. **2** also illustrates that the second enclosure space **66** is defined by the portion of the inner surface **31** of the base **30** and a lower surface **71** of the lowermost disk **34**. As used herein, "upper" is defined as the side of the disk drive **10** to which the cover **26** is attached and "lower" is defined as the side of the disk drive **10** to which the printed circuit board **18** is attached, as shown in FIG. **1**. The airflow generally follows the rotation of the disks **34**, but can be quite turbulent in the first enclosure space **62** and in the second enclosure space **66**. This turbulence greatly increases the vibration of the disks **34** under some conditions, which increases TMR of the disk drive **10**. As discussed above, this is undesirable because higher TMR limits the track pitch, and consequently limits the areal density. FIGS. **3**–**7** show various embodiments of components of the enclosure **22** that have channels to reduce the turbulence within the enclosure, e.g., in at least one of the first enclosure space **62** and the second enclosure space **66**.

FIG. **3** is a bottom plan view of one embodiment of a cover **68** that is mountable to the base **30** of the enclosure **22** of the disk drive **10**. The cover **68** has an inner surface **69**, which is the surface of the cover **68** that faces the inside of the disk drive **10** when the cover **68** is affixed to the base **30**. As discussed above, the inner surface **69** of the cover **68** and the upper surface **67** of the uppermost disk **34** define the first enclosure space **62**. Generally, the cover **68** includes a plurality of arcuate channels **70**. In particular, in one embodiment, the cover **68** includes an arcuate channel **70***a*, an arcuate channel **70***b*, and an arcuate channel **70***c* disposed generally parallel to an outer circumference of the disks **34**. In one embodiment, the arcuate channels **70***a*–**70***c* are centered on the axis **36**, and subtend a central angle between about 210 degrees and about 270 degrees. In another embodiment, the arcuate channels **70***a*–**70***c* are centered on the axis **36**, and subtend a central angle of about 240 degrees. Other embodiments of the cover **68** include more or fewer arcuate channels.

The arcuate channels **70***a*, **70***b*, and **70***c* are configured to cause the air to flow more uniformly to thereby make the airflow in the first enclosure space **62** less turbulent. Thus, the channels **70***a*, **70***b*, and **70***c* tend to reduce disk vibration that is induced by turbulent airflow within the first enclosure space **62**. By reducing turbulence in the first enclosure space **62**, the arcuate channels **70***a*, **70***b*, and **70***c* reduce vibrations in one or more of the disks **34**, the HSA **42**, the actuator arm **50**, and the suspension assembly **52**. Such reduced vibration reduces the TMR of the disk drive **10**. By reducing the TMR of the disk drive **10**, the arcuate channels **70***a*, **70***b*, and **70***c* provides for improved track pitch and areal density.

The arcuate channels **70***a*, **70***b*, and **70***c* are formed on the cover **68** in various embodiments by a stamping process, by a casting process, or by any other suitable process known to those skilled in the art. In some embodiments, the plurality of arcuate channels **70** are formed on the cover **68**, e.g., by affixing the aforementioned walls to the cover **68** with an adhesive, with at least one mechanical fastener, with a welding process, or with any other suitable process or fastener.

FIG. **4** shows the cover **68** of FIG. **3** in cross section. In one embodiment, each of the arcuate channels **70***a*, **70***b*, and **70***c* is formed between a first adjacent wall and a second adjacent wall. In particular, the arcuate channel **70***a* is formed between a first adjacent wall **74***a* and a second adjacent wall **78***a*. The arcuate channel **70***b* is formed between a first adjacent wall **74***b* and a second adjacent wall **78***b*. The arcuate channel **70***c* is formed between a first adjacent wall **74***c* and a second adjacent wall **78***c*. In the illustrated embodiment, the first adjacent walls **74***a*, **74***b*, **74***c* are located between the axis of rotation **36** and the respective second adjacent walls **78***a*, **78***b*, **78***c*. In one embodiment, each of the first adjacent walls **74***a*, **74***b*, and **74***c* and each of the second adjacent walls **78***a*, **78***b*, and **78***c*

extend from the inner surface **69** of the cover **68**, i.e., as a series of protrusions. In one embodiment, at least two of the plurality of arcuate channels **70** are adjacent one another, e.g. **70***a* and **70***b* in FIG. **4**, such that the first adjacent wall **74***a* of the arcuate channel **70***a* and the second adjacent wall **78***b* of the arcuate channel **70***b* are formed on the same protrusion. In another embodiment, the channels **70***a*, **70***b*, and **70***c* are formed as a plurality of arcuate recesses in the cover **68**.

FIG. **4**A shows an enlarged view of a portion of FIG. **4** (e.g., the channel **70***b*). Each of the arcuate channels **70***a*, **70***b*, and **70***c* comprises a channel base **82**. Each of the channels **70***a*, **70***b*, **70***c* is defined between the respective first adjacent wall **74***a*, **74***b*, **74***c* and the respective second adjacent wall **78***a*, **78***b*, **78***c*. Each of the first adjacent walls **74***a*, **74***b*, **74***c* has a first wall crest **84**. Each of the second adjacent walls **78***a*, **78***b*, **78***c* has a second wall crest **88**. In one embodiment, the transverse cross-section of at least one of the plurality of arcuate channels **70** includes a base **82** with a flat portion between the first adjacent wall **74***b* and the second adjacent wall **78***b*.

In one embodiment, a transverse cross-section of at least one of the plurality of arcuate channels **70** includes a curved portion. In another embodiment (FIG. **4**B), the transverse cross-section of at least one of the plurality of arcuate channels **70** includes a semi-circular portion. In another embodiment (FIG. **4**C), the transverse cross-section of at least one of the plurality of arcuate channels **70** (e.g., the channel **70***b*) has a substantially "V-shaped" profile, i.e., the first adjacent wall **74***b* and the second adjacent wall **78***b* of the channels **70***b* have an inclined linear side profile and the base **82** includes little to no flat portion.

In some embodiments, the dimensions of the channels **70** are important. It is presently contemplated that such dimensions will be determined experimentally. A starting point for such experimental determination is given by fluid dynamic principles. For example, the Reynolds number generally predicts whether fluid flow is generally laminar or generally turbulent for particular surrounding structure. Laminar flow, which corresponds to relatively small Reynolds numbers, tends to have a substantially uniform fluid-flow velocity. Turbulent flow, by contrast, which corresponds to relatively large Reynolds numbers, tends to have a substantially non-uniform fluid-flow velocity. The Reynolds number, Re, can be calculated as:

$$Re=[(\text{fluid density})\times(\text{fluid-flow velocity})\times(\text{characteristic length})]\div(\text{fluid viscosity}).$$

For a given flow condition, a theoretical critical Reynolds number is the number at which the fluid-flow condition changes from laminar flow to turbulent flow. In one embodiment, the arcuate channels **70** have a channel width W defined by the perpendicular distance between the first wall crest **84** and the second wall crest **88** and a channel height H defined by the height of the first wall crest **84** and/or the second wall crest **88** with respect to the channel base **82**. The channel width W can be used in the above equation as the characteristic length. Reducing characteristic length, e.g., the channel width W, will reduce the Reynolds number, contributing to more laminar airflow. The equation, thus, provides a starting point for the determination of the dimensions of one or more of the channels described herein.

FIG. **5**A illustrates another embodiment of a cover **90** that includes an outer portion **94** and a middle portion **98**. The outer portion **94** is the portion of the cover **90** that is proximate the outer circumference **49** when the cover **90** is affixed to the base **30**. The middle portion **98** is the portion of the cover **90** that is proximate the middle circumference **48** when the cover **90** is affixed to the base **30**. The embodiment of FIG. **5**A shows the arcuate channels **70** located generally toward an outer portion **94** of the cover **90**. More particularly, the arcuate channels **70** are located primarily between the outer portion **94** and the middle portion **98**. As used herein, "primarily between" means that at least one-half of the channels are disposed between the outer portion **94** and the middle portion **98**. Other embodiments concentrate the positioning of the arcuate channels **70** in various other portions of the cover **90** where turbulent flow and TMR-increasing vibrations are most likely to arise.

FIG. **5**B is a bottom plan view of another embodiment of a cover **100** of a disk drive **10**. The cover **100** has an inner surface **104**, which is the surface of the cover **100** that faces the inside of the disk drive **10** when the cover **100** is affixed to the base **30**. The cover **100** includes a plurality of arcuate channels **108**. In one embodiment, the cover **100** includes an arcuate channel **108***a*, an arcuate channel **108***b*, and an arcuate channel **108***c*. In the embodiment of FIG. **5**B, each of the arcuate channels **108***a*, **108***b*, **108***c* forms a generally closed path, e.g., subtending a central angle of about 360 degrees. The arcuate channels **108***a*, **108***b*, **108***c* are centered on the axis **36** when the cover **100** is attached to the base **30**. In another embodiment, at least one of the arcuate channels **108***a*, **108***b*, **108***c* forms a generally closed path of a different shape, e.g., an oval. Other closed-path shapes are also possible.

As discussed above in connection with the channels **70***a*, **70***b*, **70***c* of FIGS. **3** and **4**, the channels **108***a*, **108***b*, **108***c* are defined by walls having a height H with respect to the base of the channels. For example, a first adjacent wall **112***a* and a second adjacent wall **116***a* define the channel **108***a*. Similarly, a first adjacent wall **112***b* and a second adjacent wall **116***b* define the channel **108***b*. Similarly, a first adjacent wall **112***c* and a second adjacent wall **116***c* define the channel **108***c*. In one embodiment, the height H is between about 0.4 millimeters and about 3.7 millimeters. In another embodiment, the height H is between about 1.0 millimeters and about 3.0 millimeters. In another embodiment, the height H is about 2.0 millimeters. In another embodiment, the height H is about 3.5 millimeters. The height H of walls that define the channels **108***a*, **108***b*, **108***c* may be less for the embodiments having closed path channels than for the embodiment having acruate portions that subtend an angle substantially less than the 360 degrees. In another embodiment, the height H of the walls that define the channels **108***a*, **108***b*, **108***c* may be variable, so that the walls can be reduced in height in order to provide clearance for structure within the enclosure **22**, e.g., clearance for one or more portions of the HSA **42**, such as the actuator arm **50**. By making the walls variable in height, the height of the walls **112**, **116** can be similar to the height of the walls **74**, **78** where clearance is not needed for structures within the enclosure **22**.

FIG. **5**C is a bottom plan view of another embodiment of a cover **120** of a disk drive **10**. The cover **120** has an inner surface **124**, which is the surface of the cover **120** that faces the inside of the disk drive **10** when the cover **120** is affixed to the base **30**. The cover **120** includes a plurality of channels **128**. In particular, in the embodiment illustrated in FIG. **5**C, the cover **120** includes a channel **128***a*, a channel **128***b*, and a channel **128***c*. The channels **128***a*, **128***b*, **128***c* are formed by walls as in the channels **70***a*, **70***b*, **70***c*. The channel **128***a* has an upstream end **132***a* and a downstream end **136***a*. As used herein, "upstream" is defined relative to the position of the actuator arm **50** and by the direction of the rotation of the disks **34** within the enclosure **22**. (Locations proximate to

the actuator arm **50**, but located in the direction opposite of rotation of the disk (see FIG. **1**) are "upstream" of the actuator arm **50**, while locations proximate to the actuator arm **50**, but located in the direction of rotation of the disk (see FIG. **1**) are "downstream" of the actuator arm **50**.) Similarly, the channel **128***b* has an upstream end **132***b* and a downstream end **136***b*. The channel **128***c* also has an upstream end **132***c* and a downstream end **136***c*. Preferably, the width of the channels **128***a*, **128***b*, **128***c* vary along their lengths, e.g., the width of the channels **128***a*, **128***b*, **128***c* at their respective upstream ends **132***a*, **132***b*, **132***c* is narrower than the width of the channels **128***a*, **128***b*, **128***c* at their respective downstream ends **136***a*, **136***b*, **136***c*. In another embodiment, the width of the channels **128***a*, **128***b*, **128***c* at their respective downstream ends **132***a*, **132***b*, **132***c* is narrower than the width of the channels **128***a*, **128***b*, **128***c* at their respective upstream ends **132***a*, **132***b*, **132***c*.

In the illustrated embodiment, the cover **120** is also provided with a wedge-shaped portion **140** that protects the actuator arm **50** from airflow generated upstream of the actuator arm **50**. The wedge-shaped portion **140** is located between the channel **128***c* and an edge **144** of the cover **120**.

FIG. **5**D is a bottom plan view of another embodiment of a cover **150** of a disk drive **10**. In this embodiment, the cover **150** has an inner surface **154** that includes a plurality of channels **158**. The channels **158** are similar to the plurality of arcuate channels **70**, except that they subtend a central angle that is generally much less than the central angle subtended by the plurality of arcuate channels **70**. In one embodiment, the plurality of arcuate channels **158** are on the cover **150** so that when the cover **150** is affixed to the base **30**, the plurality of arcuate channels **158** are located upstream of the actuator arm **50**. In other embodiments, the channels **158** are located downstream of the actuator arm **50**. In another embodiment, the channels **158** are located roughly midway between the upstream side of the actuator arm **50** and the downstream side of the actuator arm **50**.

FIG. **5**E is a bottom plan view of another embodiment of a cover **170** of a disk drive **10**. The cover **170** includes an inner surface **174**. The cover **170** includes a plurality of channels **178**. As with the channels **70**, the channels **178** are formed by walls having a height H with respect to the base of the channels. An imaginary line **182** corresponds to the rotary path that the data transfer head **54** traces out beneath the cover **170** when the cover **170** is affixed to the base **30** and the disk drive **10** is operating. In one embodiment, each of the channels **178** is somewhat elongated, and therefore have a longitudinal axis **186**. Each of the channels **178** is located on the cover **170** and is formed such that the longitudinal axis **186** is generally perpendicular to the line **182**, which traces out the rotary path of the data transfer head **54**. In one embodiment, the channels **178** are located on the cover **170** such that when the cover **170** is affixed to the base **30** and the disk drive **10** is operating, the data transfer head **54** passes between the channels **178** and the disks **34**. In another embodiment, the channels **178** are located on the cover **170** such that when the cover **170** is affixed to the base **30** and the disk drive **10** is operating, the data transfer head **54** is generally upstream of the channels **178**. In another embodiment, the channels **178** are located on the cover **170** such that when the cover **170** is affixed to the base **30** and the disk drive **10** is operating, the data transfer head **54** is generally downstream of the channels **178**.

FIGS. **6** and **7** illustrate an embodiment of a base **200** of the enclosure **22**. The base **200** has a plurality of arcuate channels **204**. The arcuate channels **204** are similar to the arcuate channels **70**. The base **200** is similar to the cover **68** of FIGS. **3** and **4**, except that the pattern of the arcuate channels **204** is the mirror image of the pattern of the channels **70**. The channels **204** can be produced by a machining process, a casting process, or by any other suitable process. As with the channels **70**, the channels **204** could also be formed on the base **200**, e.g., by affixing walls to the base with an adhesive, with a mechanical fastener, or with any other suitable process or fastener. As with the arcuate channels **70**, the arcuate channels **204** could form closed path channels (e.g., circular channels similar to those shown on the cover of FIG. **5**B), or the channels **204** could subtend a central angle of less than 360 degrees (see FIG. **6**). In one embodiment, the arcuate channels **204** subtend a central angle between about 210 degrees and about 270 degrees. In another embodiment, the arcuate channels **204** subtend a central angle of about 240 degrees.

The base **200** can also be configured with a pattern of channels that is the mirror image of the pattern of channels of the other cover configurations. As with the cover **90** (FIG. **5**A), a base could be configured with channels **204** concentrated in one or more portions of an inner surface of the base. As with the cover **120** (FIG. **5**C), the base **200** could have channels **204** having varying channel widths. As with the cover **150** (FIG. **5**D), the base **200** could be formed with channels **204** that subtend a central angle that is much less than the central angle shown in FIG. **6**, e.g., between about 15 degrees and about 30 degrees. As with the cover **170** (FIG. **5**E), the base **200** could be provided with channels **204** that are formed on the base and oriented so that the longitudinal axis of the channels **204** is generally perpendicular to the path traced out by the rotary motion of the data transfer head **54**.

As with the arcuate channels **70**, the arcuate channels **204** are configured to make the airflow in the second enclosure space **66** less turbulent. By reducing turbulence in the second enclosure space **66**, the arcuate channels **204** reduce vibrations in one or more of the disks **34**, the HSA **42**, the actuator arm **50**, and the suspension assembly **52**. Such reduced vibration reduces the TMR of the disk drive **10** and thereby improves the track pitch and areal density of the disk drive **10**.

One skilled in the art will appreciate that an enclosure **22** could be provided with the cover **68** having the arcuate channels **70** and with the base **200** having the arcuate channels **204**. In this embodiment, the arcuate channels **70** are configured to make the airflow in the first enclosure space **62** less turbulent. The arcuate channels **204** are configured to make the airflow in the second enclosure space **66** less turbulent. Thus, the arcuate channels **70** and the arcuate channels **204** tend to reduce vibrations in one or more of the disks **34**, the HSA **42**, the actuator arm **50**, and the suspension assembly **52**. This embodiment reduces the TMR of the disk drive **10** is reduced even more than when only one of the arcuate channels **70** and the arcuate channels **204** are used. This improves track pitch and, consequently, improves areal density.

One skilled in the art should recognize that other combinations are also possible. For example, any of the covers **68**, **90**, **100**, **120**, **150**, and **170** could also be used with the base **200**. Also, any of the covers **68**, **90**, **100**, **120**, **150**, and **170** could be combined with a base **200** having channels **204** concentrated in one or more portions of the inner surface of the base **180** or with a base having channels **204** that are formed as closed paths. Also, any of the covers **68**, **90**, **100**, **120**, **150**, and **170** could be combined with a base **200** having channels **204** that have varying widths or with a base **200** having closed path channels **204** that subtend an angle that

is much less than the central angle shown in FIG. **6**, e.g., between about 15 degrees and about 30 degrees. Also, any of the covers **68**, **90**, **100**, **120**, **150**, and **170** could be combined with a base **200** having channels **204** that are located on the base such that their longitudinal axes are perpendicular to the path traced out by the rotary motion of the data transfer head **54**.

What is claimed is:

1. A disk drive comprising:

an enclosure having a base and a cover;

a disk that rotates about an axis within the enclosure, the rotating disk having an axis of rotation and a magnetic medium formed on at least one surface thereof, the rotating disk creating airflow within the enclosure;

an actuator arm that positions a data transfer head proximate the surface of the disk; and

a plurality of arcuate channels located on a face of the enclosure that is approximately parallel to the at least one surface of the disk, each of the plurality of arcuate channels being disposed within said airflow and comprising two arcuate adjacent walls and a channel base that is located between the two arcuate adjacent walls, each of the arcuate adjacent walls being oriented concentrically about the axis of rotation of the disk, and each of the arcuate adjacent walls extending closer to the at least one surface of the disk than does the channel base.

2. The disk drive of claim **1**, wherein the face of the enclosure is an approximately planar surface.

3. The disk drive of claim **1**, wherein the face of the enclosure is an approximately planar surface of the base.

4. The disk drive of claim **1**, wherein the face of the enclosure is an approximately planar surface of the cover.

5. The disk drive of claim **1**, wherein each of the arcuate adjacent walls extends from the face of the enclosure by a height in the range 0.4 mm to 3.7 mm.

6. The disk drive of claim **1**, wherein a transverse cross-section of each of the plurality of arcuate channels comprises a curved portion.

7. The disk drive of claim **1**, wherein a transverse cross-section of each of the plurality of arcuate channels comprises a semi-circular portion.

8. The disk drive of claim **1**, wherein each of the plurality of arcuate channels subtends a central angle between about 210 degrees and about 270 degrees.

9. The disk drive of claim **1**, wherein each of the plurality of arcuate channels subtends a central angle of about 240 degrees.

10. The disk drive of claim **1**, wherein each of the plurality of arcuate channels subtends a central angle of about 360 degrees.

* * * * *

2. U.S. Patent No. 6,882,501 B2, referred to herein as "Machcha." Machcha was entered into the record by the Examiner in the Office communication mailed 07/27/2006 at paragraph 8.

US006882501B2

(12) **United States Patent**
Machcha et al.

(10) **Patent No.: US 6,882,501 B2**
(45) **Date of Patent: Apr. 19, 2005**

(54) **FLOW MODIFICATION FOR REDUCING TRACK MISREGISTRATION IN HARD DISK DRIVES**

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(73) Assignee: **Maxtor Corporation**, Longmont, CO (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

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(65) **Prior Publication Data**

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(52) **U.S. Cl.** **360/97.03**
(58) **Field of Search** 360/97.03, 97.02, 360/97.01, 88

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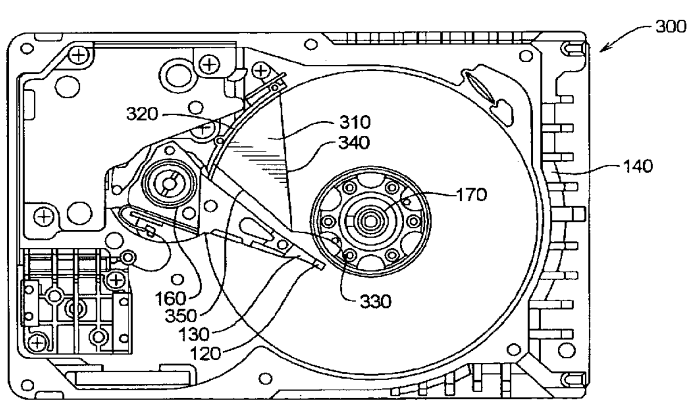
Primary Examiner—Julie Anne Watko

(57) **ABSTRACT**

Systems and apparatus are described for modifying fluid flow in a hard disk drive system to reduce cross-track motion. The systems and methods provide advantages because they include at least one flow modification element. In some embodiments, the flow modification system comprises a set of approximately parallel combs occupying a portion of the space present in between the disks in the hard disk drive system. The combs change the flow pattern of the fluid and act as a momentum channeling mechanism relative to the actuator assembly and suspension assemblies resulting in a considerable reduction in track misregistration error. Various embodiments of the invention include baffle-integrated combs, fixture-integrated combs, contoured enclosure surfaces, and enclosure attached combs.

17 Claims, 5 Drawing Sheets



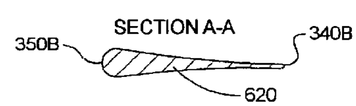


FIG. 1
PRIOR ART

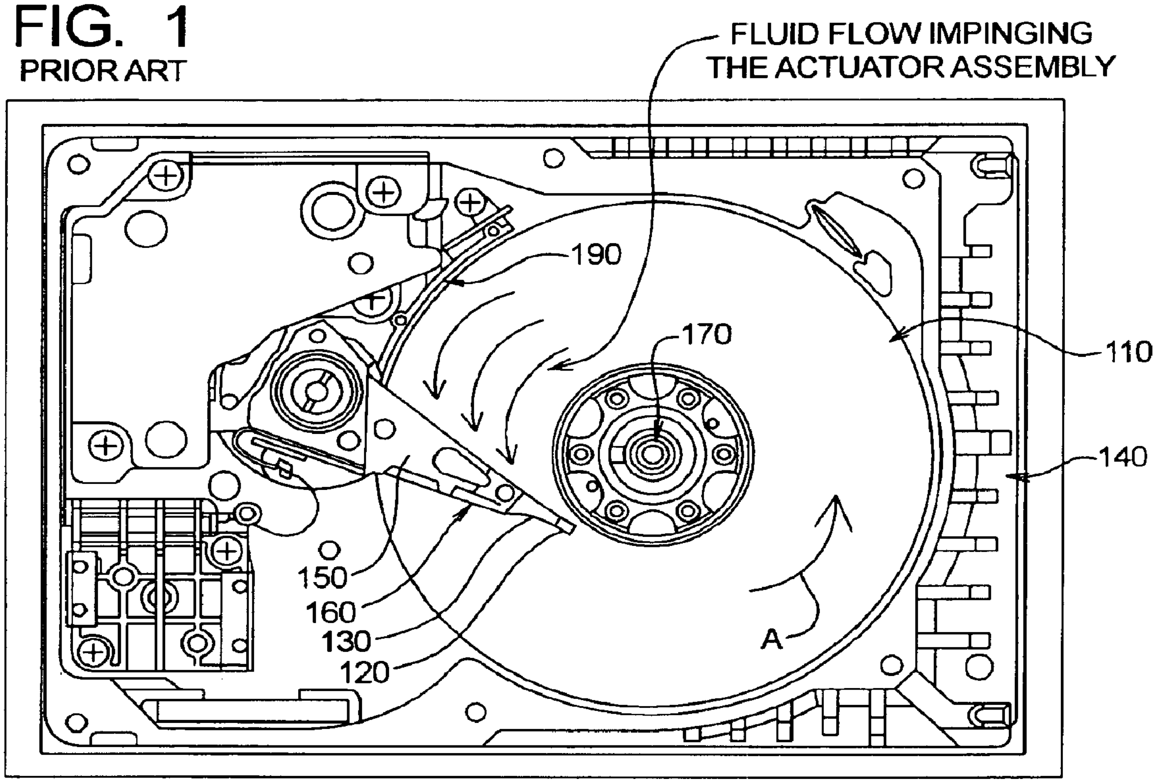


FIG. 2
PRIOR ART

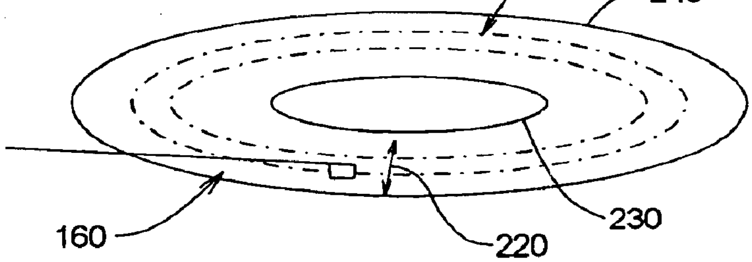


FIG. 3A

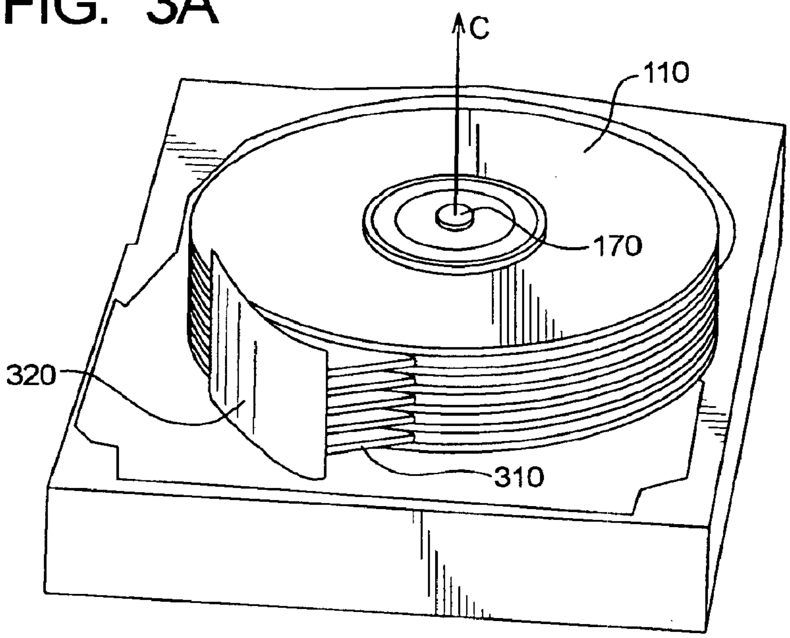
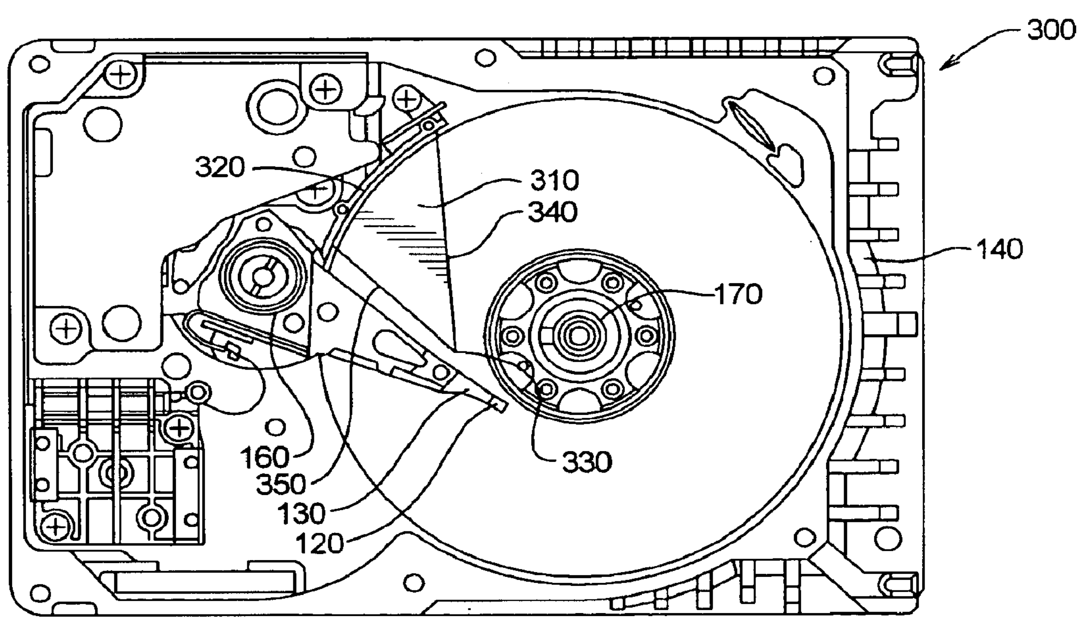


FIG. 3B



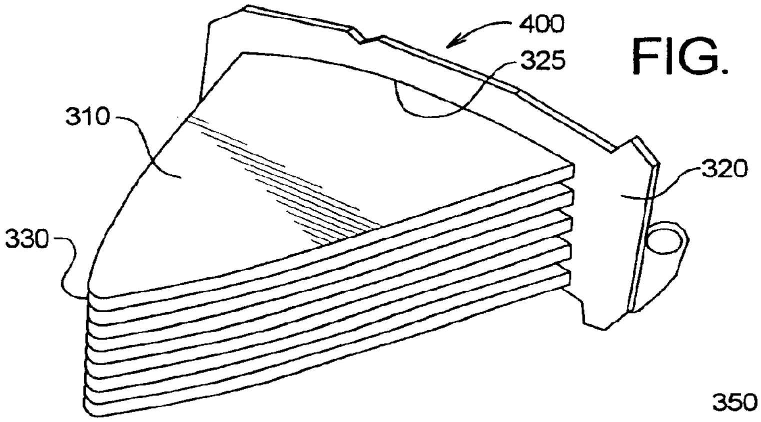


FIG. 4

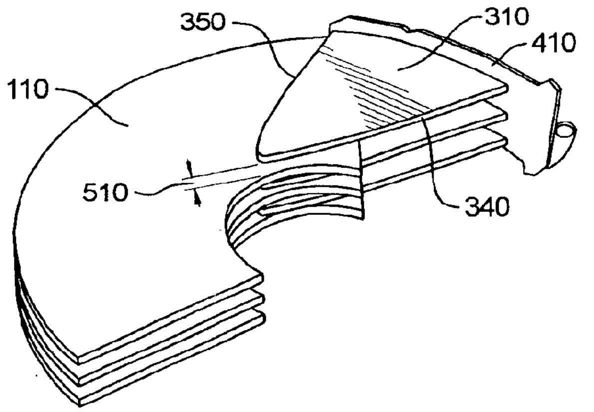


FIG. 5

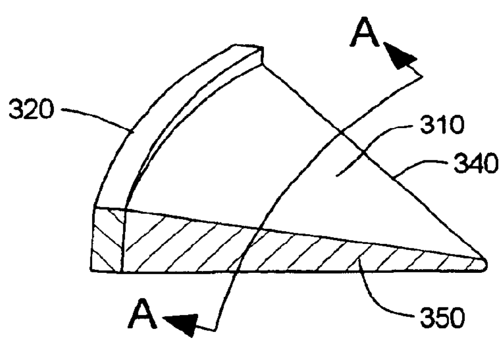


FIG. 6A

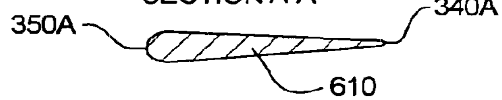


FIG. 6B
SECTION A-A

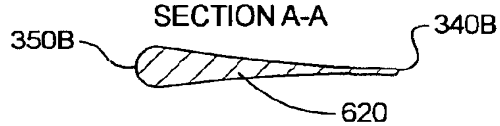


FIG. 6C
SECTION A-A

FIG. 7A

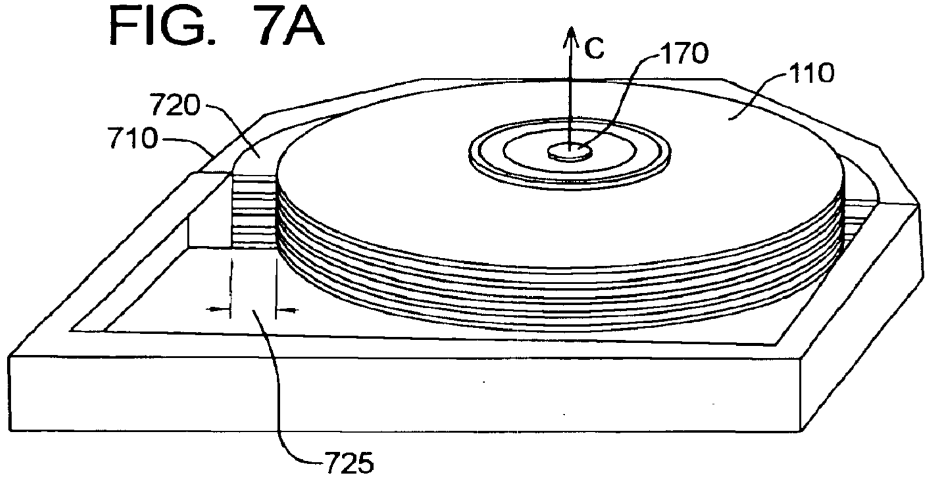


FIG. 7B

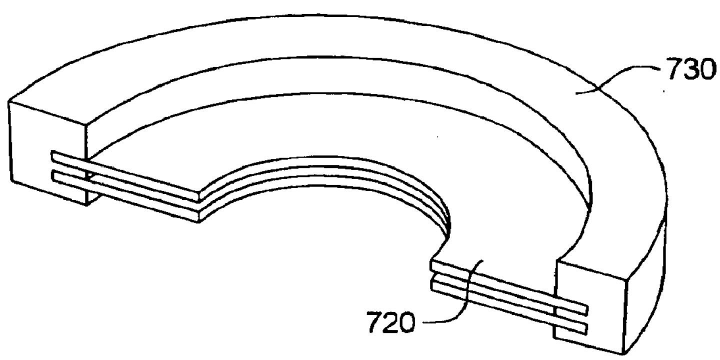


FIG. 7C

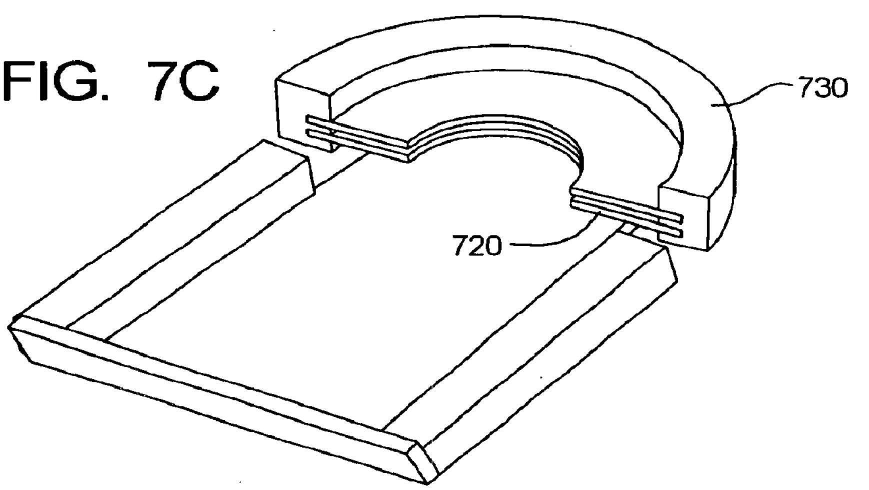


FIG. 8A

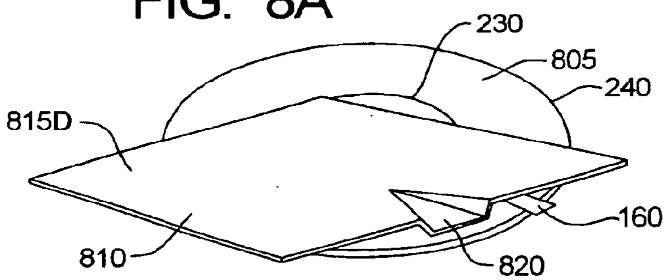


FIG. 8B

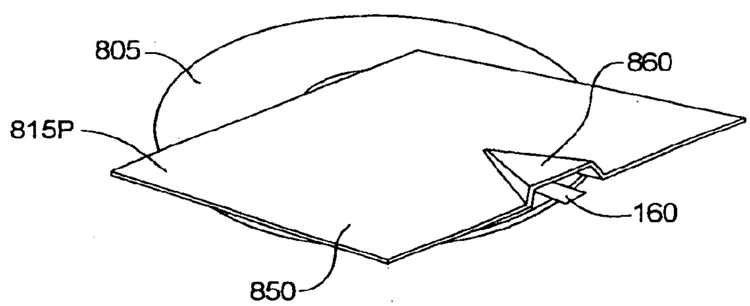


FIG. 9A

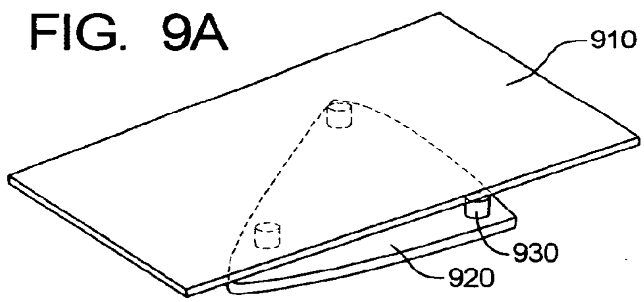
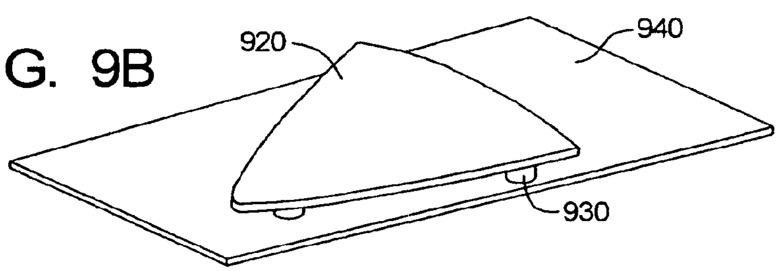


FIG. 9B



FLOW MODIFICATION FOR REDUCING TRACK MISREGISTRATION IN HARD DISK DRIVES

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates generally to the field of hard disk drives. More particularly, the invention relates to hard disk drives having at least one flow modification element disposed adjacent to at least one data storage disk.

2. Discussion of the Related Art

Conventional hard disk drive **100**, a portion of which is shown in FIG. **1**, includes at least one rotating disk **110** on which data is stored in concentric tracks. Disk drive **100** includes read-write head **120** disposed on aerodynamically operable slider assembly **130** and back plate **140**. Slider assembly **130** is disposed at the end of the actuator arm portion of actuator assembly **160**. Disk **110** couples with spindle **170** to rotate in a counterclockwise direction (shown as "A" in FIG. **1**), thereby causing airflow in direction A. The airflow impinges upon portions of actuator assembly **160** and slider assembly **130**. Movement of actuator assembly **160** is accomplished using a conventional voice coil motor (not shown in FIG. **1**).

Head **120** reads data from and writes data to approximately concentric data tracks **210**, shown schematically in FIG. **2**. While disk drive **100** is in operation, actuator assembly **160** experiences cross-track motion **220** as head **120** attempts to follow track **210**.

Cross track motion **220** of head **120** can be measured as track misregistration (TMR). Larger levels of TMR limit the amount of data that can be written to and retrieved from disk drive **100**. Cross track motion **220** results from several disturbances that couple into head **120**. Some of the major disturbances include disk vibration, spindle bearing runout (repeatable and non-repeatable), slider assembly **130** vibration, actuator arm vibration, and drive enclosure vibration.

In order to accurately read and write data, a servo control system is employed to keep head **120** aligned with track **210**. The servo control system has its own attenuation and amplification characteristics, and is typically ineffective above about 4 kHz. Head **120** vibration spectrums for conventional disk drives **100** exhibit substantial vibrational movement of head **120** in a high frequency region of around 5 to 25 kHz. The servo control system is ineffective in compensating for the vibration in the high frequency region.

A common approach to increase the storage capacity of a disk drive **100** is to increase the track **210** density (tracks per inch, or TPI). Due to the continuing push for greater track **210** densities, allowable cross track motion **220** is decreasing in absolute terms. However, drives are spinning at higher speeds. Higher speeds increase the amount of cross track motion **220** of head **120**. The increase in TMR (i.e., cross track motion **220**) in the high frequency region is more pronounced at higher disk rotation speeds. A drive is typically designed so that the total TMR cannot exceed a certain limit (e.g., approximately ten percent of the track **210** width). As a result of this limit, at higher rotational speeds, no remaining TMR budget is available at the higher rotational frequencies, and the vibrational energy within the TMR spectral bandwidth of 0–25 kHz frequency range needs to be minimized in order to provide error-free operation of disk drives **100**.

Disk drives **100** are known to those skilled in the art. For example, a conventional disk drive **100**, such as the disk drive described by U.S. Pat. No. 5,526,203, can include baffle **190** disposed adjacent to upstream from actuator assembly **160**. Baffle **190** is placed adjacent to the outermost diameter of disks **110**. According to the U.S. Pat. No. 5,526,203 patent, one motivation for using baffles **190** is to block contaminants generated by actuator assembly **160** from being deposited on disks **110**. Baffles **190** have the unintended effect of blocking airflow that would otherwise impinge on portions of actuator assembly **160** disposed outside outer edges **240** of disks **110**. Such airflow blocking can reduce TMR in some designs.

However, baffles **190** cannot effectively reduce the airflow contributions (or momentum transfer) that cause cross track motion **220**. Baffles **190** do not modify the airflow interaction with portions of actuator assembly **160** disposed between disks **110**. Therefore, what is required is a solution that reduces the momentum transfer caused by airflow impinging these portions of actuator assembly **160** adjacent to disk **110** data surfaces. The reduction of momentum transfer decreases cross track motion **220** of head **120**. Heretofore, the requirement of reduced cross track motion **220** referred to above has not been fully met.

SUMMARY OF THE INVENTION

One goal of the invention is to reduce cross track motion **220** in a disk drive. Another goal of the invention is to provide a comb, or other device to reduce cross track motion **220** in a disk drive.

A first aspect of the invention is implemented in embodiments that are based on a baffle integrated comb disk drive. The disk drive includes a spindle, data storage disks, slider assemblies, an actuator assembly, a baffle, and combs. The spindle is adapted to rotate about a longitudinal axis. The disks are surrounded by fluid medium. The disks are mounted on the spindle to rotate therewith about the spindle longitudinal axis. Rotation of the disks in a first direction (indicated by "A" in FIG. **1**) creates a flow of the fluid medium in the first direction. At least one of the disks has approximately concentric tracks disposed at different radial positions between the disk's outer edge and the disk's inner edge. Each slider assembly includes at least one transducer head capable of reading and writing information on one of the disks. The actuator assembly positions the slider assemblies over the tracks.

The baffle is disposed upstream of the actuator assembly. The baffle extends in the direction of the spindle longitudinal axis and has an inner surface disposed at least one millimeter outside of the outer edges of the disks.

The combs are mounted on the baffle. At least one of the combs is disposed adjacent to at least one of the disks to form a gap between the comb and a corresponding adjacent disk. The gap is disposed in the direction of the spindle longitudinal axis and is in a range from approximately 0.1-millimeter to approximately 20 millimeters. At least one of the combs extends radially inward from a comb outer edge to a comb inner edge. A portion of the comb outer edge is disposed at the inner surface of the baffle. At least one of the combs is disposed upstream of a corresponding actuator assembly. At least one of the combs extends in a disk circumferential direction from a leading edge to a trailing edge. The leading edge is disposed upstream of the trailing edge. At least one of the combs extends radially inward from the baffle plate more than approximately two percent of a distance between an inner edge and the outer edge of the corresponding adjacent disk.

A second aspect of the invention is implemented in embodiments that are based on a fixture integrated comb disk drive. These embodiments include a comb fixture coupled with combs. The comb fixture is disposed apart from the actuator assembly, and has an inner surface separated by a first distance from the outer edges of the disks. The first distance is greater than approximately one millimeter.

The combs extend inwardly from the comb fixture. At least one of the combs is disposed adjacent to a corresponding adjacent disk to provide a gap between the comb and the corresponding adjacent disk. The gap is disposed in the direction of the spindle longitudinal axis and is in a range from approximately 0.1 millimeters to approximately 20 millimeters. At least one comb extends circumferentially around the spindle longitudinal axis.

A third aspect of the invention is a disk drive with at least one contoured enclosure element. Embodiments according to this aspect can have one or more of the following enclosure elements. The first type of enclosure element according to this aspect comprises a first large portion and a depressed contoured portion with a depressed region. The second type of enclosure element according to this aspect of the invention includes a second large portion and a protruded contoured portion with a protruded region.

The first large portion has a surface proximal to an adjacent disk outer surface and is disposed longitudinally outside the actuator assembly to form a gap in approximately the longitudinal direction between the first large portion proximal surface and the adjacent disk outer surface of at least approximately 0.1 millimeter. The depressed contoured portion is disposed circumferentially adjacent to and upstream of the actuator assembly. The depressed region is disposed closer to the adjacent disk outer surface than the first large portion. The first large portion covers more than approximately three times the amount of the adjacent disk outer surface than the amount of the outer surface that is covered by the depressed region.

The second large portion has a surface proximal to the adjacent disk outer surface and forms a gap in approximately the longitudinal direction between the second large portion proximal surface and the adjacent disk outer surface of no more than approximately 20 millimeters. The protruded region is disposed longitudinally outside the actuator assembly. The protruded region has a width outside the outer edge of the adjacent disk greater than a width of a portion of the actuator assembly adjacent and longitudinally interior of the protruded region. The protruded region is disposed farther from the adjacent disk outer surface than the second large portion. The second large portion covers more than approximately three times the amount of the adjacent disk outer surface than the amount of the outer surface that is covered by the protruded region.

These, and other, goals and aspects of the invention will be better appreciated and understood when considered in conjunction with the following description and the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

A clear conception of the advantages and features constituting the invention, will become more readily apparent by referring to the exemplary, and therefore non-limiting, embodiments. The embodiments are illustrated in the drawings, wherein like reference characters (if they occur in more than one view) designate the same parts. It should be noted that the features illustrated in the drawings are not necessarily drawn to scale.

FIG. **1** is a top view of a portion of a conventional disk drive.

FIG. **2** is a schematic view of the top of a data storage disk and actuator arm.

FIG. **3**A is a perspective view of the front of portions of a disk drive having combs integrated into a baffle, representing a first embodiment of the invention.

FIG. **3**B is a top view of a portion of a baffle integrated comb disk drive, representing the first embodiment of the invention.

FIG. **4** is a perspective view of an integrated baffle/comb assembly having a baffle plate.

FIG. **5** is a perspective view illustrating how the baffle-integrated combs assemble into the space between the data storage disks.

FIGS. **6**A–**6**C provide different cross-sectional views of circumferentially tapered comb designs used in the present invention.

FIG. **7**A is a perspective view of a portion of disk drive having fixture-integrated combs, representing a second embodiment of the invention.

FIG. **7**B is a perspective view of fixture integrated combs coupled with disk drive back plate having a fixture integrated therein.

FIG. **7**C is a perspective view of the fixture-integrated combs including some additional portions of the disk drive.

FIGS. **8**A and **8**B are perspective views of contoured cover plates, used in the present invention.

FIG. **9**A is a perspective view of combs attached directly to a disk drive cover plate.

FIG. **9**B is a perspective view of combs attached directly to a disk drive base plate.

DESCRIPTION OF PREFERRED EMBODIMENTS

The invention and the various features and advantageous details thereof are explained more fully with reference to the non-limiting embodiments that are illustrated in the accompanying drawings and detailed in the following description of preferred embodiments. Descriptions of well-known components and processing techniques are omitted so as not to unnecessarily obscure the invention in detail.

The invention reduces cross-track motion **220** of read-write head **120** over the complete spectral bandwidth of interest for a disk drive by introducing components that alter fluid movement in the disk drive. The reduction of cross-track motion **220** is accomplished by reducing the total cross-track momentum of fluid molecules that interact with disk drive components. The fluid can be air or another fluid, such as helium. Considerable decreases in design effort for dynamic disk drive components can be realized by implementing the invention with passive components. These passive components can be introduced at low cost and allow greater disk drive design flexibility.

A portion of a baffle-integrated comb (BIC) disk drive **300** according to the principles of the invention is depicted in FIG. **3**A and **3**B. Placing flow modifier combs, such as baffle integrated combs **310**, in the space between disks **110** of BIC disk drive **300** reduces the fluid molecule momentum transfer to key portions of BIC disk drive **300**. Baffle-integrated comb disk drives **300** typically have more than one disk **110**. However, in some embodiments, two combs can be used according to the invention for a disk drive that has only one data disk.

Combs **310** provide a considerable reduction in cross-track motion **220** in all disturbance frequency regions, but particularly for the high frequency region (where the servo control system is not effective). Combs **310**, and other flow modification elements according to the invention, are placed very close to corresponding adjacent rotating disks **110** to modify the flow characteristics of the fluid medium moved by disks **110**.

The primary energy source for the fluid flow and other vibration disturbances of read-write head **120** is rotating spindle **170**. The energy from spindle **170** is mainly partitioned off into the mechanical components of the corresponding disk drive (such as BIC disk drive **300**), the fluid medium inside the drive enclosure, and as heat. Fluid medium receiving energy from spindle **170** serves as a secondary source of excitation for components inside BIC disk drive **300**, so that the fluid medium flow affects the amount of cross-track motion **220**. Cross-track motion **220** motion is a direct result of the momentum transfer that takes place as the high-energy fluid molecules impinge actuator assembly **160**.

Designing or locating the combs so that an energy dissipating flow region is developed also reduces this transfer of momentum. Because the comb acts as an obstruction to the normal flow of the rotating fluid, the fluid flow becomes very complex after interacting with the comb. The contact of the fluid with the comb results in flow separation, creation of vortices and mixing. These effects change the momentum vectors of the fluid molecules to a direction other than the nominal flow direction (shown as "A" in FIG. **1**). This change in the fluid molecule momentum vectors translates into smaller momentum vectors of the fluid molecules in the cross-track motion **220** direction in the region of operation for actuator assembly **160**. Further beneficial effects can be obtained through selection of materials and component geometry. Examination of FIG. **3**B in conjunction with FIG. **1** and FIG. **2**, reveals that fluid flow impingement on suspension arm **150**, slider assembly **130** and read-write head **120** causes movement of these components in a direction that is not parallel to the track **210** direction. This non-parallel movement occurs because suspension arm **150** extends lengthwise in a direction other than the radial direction of disk **110**. The angle between the radial direction and the suspension arm **150** lengthwise direction increases for tracks **210** disposed on the outer diameter of disk **110**.

Introducing the comb increases power consumption due to cross-sectional and surface drag of the fluid medium. The higher power budget for the BIC drive **300** can be accommodated by careful selection of a comb unit design, or by considering other power saving mechanisms and designs, such as a lower number of disks **110**, thinner disks **110** etc. These power reduction options are more readily available because of reduced cross-track motion **220** provided by the combs. Using fewer disks **110** also decreases the cost for read-write heads **120** in a disk drive.

Baffle Integrated Combs

One aspect of the invention provides a baffle integrated comb assembly for reducing cross track motion in a baffle integrated comb disk (BIC) drive. Portions of BIC drive **300** are shown in FIG. **3**A and FIG. **3**B. Some embodiments of baffle/comb assemblies **400** according to this aspect are illustrated in FIG. **4** and FIG. **5**. BIC drive **300** comprises spindle **170**, data storage disks **110**, slider assemblies **130**, actuator assembly **160**, baffle integrated combs **310** and baffles **320**.

Spindle **170** is conventionally coupled with a spindle motor to rotate about spindle longitudinal axis (shown as "C" in FIG. **3**A) when BIC disk drive **300** is powered on. Each disk **110** is mounted on spindle **170** to rotate therewith about the spindle longitudinal axis in a first direction (e.g., either clockwise or counterclockwise around spindle longitudinal axis). Each disk **110** has an inner edge **230** and an outer edge **240**. At least one of disks **110** has concentric tracks **210** disposed at different radial positions between inner edge **230** and outer edge **240**. Rotating disks **110** create a flow of fluid medium contained in BIC drive **300** in the first direction.

BIC drive **300** shown in FIG. **3**B includes conventional slider assemblies **130**. Each slider assembly **130** includes at least one transducer head capable of reading and writing information on one of disks **110**. BIC drive **300** also includes actuator assembly **160** for positioning slider assemblies **130** over concentric tracks **210**.

BIC drive **300** includes a baffle/comb assembly **400** having integrated baffle **320** disposed upstream of actuator assembly **160**. Baffle **320** extends in the direction of the spindle **170** longitudinal axis and has an inner surface disposed at least one millimeter outside of the outer edges **240** of disks **110**.

As shown in FIG. **4**A and FIG. **5**, baffle integrated combs **310** are mounted on baffle **320**. Each comb **310** is disposed adjacent to at least one disk **110** to form a comb-to-disk spacing **510** between comb **310** and a corresponding adjacent disk **110**. Comb to disk spacing **510** is oriented approximately in the direction of the spindle **170** longitudinal axis and is in a range from approximately 0.1-millimeter to approximately 20 millimeters. In some embodiments, comb to disk spacing **510** is less than approximately 0.4 millimeters.

At least one comb **310** extends radially inward from a comb outer edge (otherwise referred to as a comb "base" **325**) to a comb inner edge. B-comb base **325** is disposed approximately at the inner surface of baffle **320**. The comb inner edge for triangular shaped combs comprises comb tip **330**.

Each comb **310** is disposed upstream of a corresponding actuator assembly **160**, and, as shown in FIG. **5**, extends in a disk **110** circumferential direction from a leading edge **340** to a trailing edge **350**. Leading edge **340** is disposed upstream of trailing edge **350**.

As shown in FIG. **3**B, each comb **310** extends radially inward from baffle **320** more than approximately two percent of a radial separation distance between disk inner edge **230** and disk outer edge **240** of a first adjacent disk **110**.

Typically, comb's **310** maximum radially inward extent is approximately thirty to eighty percent (30–80%) of the disk inner edge **230** to disk outer edge **240** radial separation distance. As shown in FIG. **3**B, comb **310** trailing edge is typically approximately parallel to the leading edge of actuator assembly **160** when actuator assembly **160** is positioned to read data track **210** near disk inner edge **230**.

Combs **310** can be manufactured by molding the whole of baffle/comb assembly **400** at once. Baffle/comb assembly **400** can be machined as a single piece. For these single piece baffle/comb assembly **400** approaches baffle **320** comprises a baffle plate. Alternatively, combs **310** can produced as individual pieces and stacked one on top of the other. Each individual piece includes a baffle element **410** extending radially outward from comb base **325**. Each baffle element **410** typically has a greater thickness than its corresponding comb **310** to provide space between adjacent B-combs for corresponding disks **110**. The baffle/comb assembly **400** using individual comb **310** pieces does not need a baffle plate.

In some embodiments, BIC disk drive **300** includes a second set of combs extending radially inward from an outer attachment element inner surface. The second set of combs can be baffle integrated combs **310**, or fixture integrated combs (as described below with reference to FIG. **7**A). The outer attachment element inner surface has a diameter greater than the outer edge of disks **110**, each of the second set of combs is disposed in a position adjacent to at least one disk **110**, and is disposed downstream of slider assemblies **130**. The slider assemblies **130** are disposed on the distal end of actuator assembly **160**.

In some embodiments, at least one of comb **310** comprises more than one element. At least two of the comb elements are separated from each other by an intra-comb gap. The intra-comb gap extends radially from approximately the comb **310** inner diameter to approximately the comb outer diameter.

In some embodiments, at least one comb **310** has a textured surface adapted to modify a fluid flow impinging on an adjacent slider assembly **130**. For example, very-small v-shaped grooves disposed on either the distal or the proximal comb **310** surface (or on both surfaces) and oriented in a direction approximately perpendicular to the fluid flow results in decreased drag losses and concomitant power consumption reduction.

As shown in FIGS. **6**A–**6**C comb **310** can be tapered so that the comb thickness increases form leading edge **440** to trailing edge **450**. Comb **310** can have an approximately constantly sloped taper as shown in FIG. **6**B, or alternatively can have a variably sloped taper as shown for example in FIG. **6**C where the slope generally increases as the thickness of the B-comb increases.

As shown in FIG. **6**A, at least one comb **310** can also have a thickness that increases from the comb inner diameter to the comb outer diameter.

Fixture Integrated Combs

A portion of a fixture integrated comb (FIC) disk drive **700** is shown in FIGS. **7**A–**7**C. The FIC disk drive **700** has a comb fixture **710** integrated with a back plate or other portion of a disk drive. FIC disk drive **700** includes the conventional elements described above for BIC disk drive **300**. As shown in FIG. **7**A, comb fixture **710** is disposed apart from actuator assembly **160**, and has an inner surface separated in an approximately radial direction from the disk outer edge **240** by a fixture to disk spacing **725**. Fixture to disk spacing **725** is greater than approximately one millimeter.

Fixture integrated combs **720** are coupled with and extend inwardly from comb fixture **710**. Similar to baffle integrated combs **310**, each fixture integrated comb **720** is disposed adjacent to a corresponding adjacent disk **110** to form a comb to disk spacing **510** between the comb and the adjacent disk. Comb to disk spacing **510** is disposed in the direction of the spindle longitudinal axis (shown as "C" in FIG. **7**A) and is in a range from approximately 0.1 millimeters to approximately 20 millimeters. In some embodiments, comb to disk spacing **510** is less than approximately 0.4 millimeters.

Comb **720** extends inwardly at least two percent of a distance from comb fixture **710** to disk inner edge **230** of the corresponding adjacent disk. Comb **720** extends circumferentially around the spindle **170** longitudinal axis. Typically, comb **720** extends circumferentially through an angular distance of at least twenty degrees.

Various embodiments of FIC disk drive **700** have been developed. For some embodiments comb **720** includes a first portion and a second portion. The first portion has an outer diameter approximately equal to the comb fixture **710** inner surface. The second portion extends closer to the slider assemblies **130** and has an outer diameter less than the comb fixture **710** inner surface. Other combs **720**, do not include such distinct portions.

In some embodiments, FIC disk drive **700** includes baffle **190** disposed outside disk **110** outer edges **240**. Baffle **190** also has an edge spaced closely to a segment of disk outer edges **240**. For these FIC disk drives **700** a first portion of the at least one comb **720** extends radially inward beyond the outer edge **240** of the corresponding adjacent disk **110**. An edge of the first portion of comb **720** proximal to disk outer edge **240** extends circumferentially towards actuator assembly **160** forming a gap between the proximal edge of comb **720** and baffle **190** of no less than ten millimeters.

Contoured Enclosure Surfaces

Another aspect of the invention provides a disk drive with at least one enclosure element with a contoured surface. The contoured enclosure surface reduces cross-track motion **220**. The contoured surface can be a portion of a cover plate or a portion of a base plate that provides the desired fluid flow modification in the disk drive. Portions of two embodiments of this aspect of the invention are shown in FIG. **8**A and FIG. **8**B.

Other than the contoured enclosure surface, disk drives according to this aspect typically have the conventional elements described above for BIC drive **300**. As shown in FIG. **8**A and FIG. **8**B, disk **110** has outer edge **240**, outer surface **805**, inner edge **230**, and an inner surface (not shown). The inner surface and outer surface **805** are approximately perpendicular to the spindle longitudinal axis (shown as "C" in FIG. **3**).

The enclosure element can include a large somewhat flat portion combined with a depressed contoured portion, such as a cover plate with a depressed contour (depressed contour cover plate **810**) as shown in FIG. **8**A. Depressed contour cover plate **810** includes large cover plate portion **815**D and a depressed contoured portion having a depressed region **820**. The proximal surface of depressed region **820** provides flow modification for outer surface **805** of the uppermost disk in a disk drive similar to the flow modification provided by baffle integrated comb **310** or fixture integrated comb **720**. Large portion **815**D has a surface (e.g., the bottom side of depressed contour cover plate **810**) proximal to an adjacent disk outer surface **805**. The proximal surface of large portion **815**D is disposed longitudinally outside (e.g. above) actuator assembly **160** to form a gap in approximately the longitudinal direction between the proximal surface of large portion **815**D and outer surface **805** of at least approximately 0.1 millimeter. The depressed contoured portion is disposed circumferentially adjacent to and upstream of actuator assembly **160**. Depressed region **820** is disposed closer to outer surface **805** than large portion **815**D. In some embodiments the distance between depressed region **820** and outer surface **805** is less than approximately 0.8 millimeters. Large portion **815**D typically covers more than approximately three times the amount of outer surface **805** covered by depressed region **820**.

For other embodiments according to this aspect the enclosure element can be a large somewhat flat portion combined with a protruded contoured portion such as a cover plate with a protruded contour (protruded contour cover plate **850**) as shown in FIG. **8**B. Protruded contour cover plate **850** includes large P-cover plate portion **815**P and protruded contour portion having a protruded region **860**. Large portion **815**P has a surface proximal to outer surface **805** and forms a gap in approximately the longitudinal direction

between the proximal surface and outer surface **805** of no more than approximately 20 millimeters. Protruded region **860** is disposed above actuator assembly **160**. Protruded region **860** has a width above the of the adjacent disk outer edge **240** greater than a width of a portion of actuator assembly **160** adjacent and longitudinally interior of the protruded region **860**. Protruded region **860** is disposed farther from outer surface **805** than large portion **815P**. Large portion **815P** typically covers more than approximately three times the amount of outer surface **805** covered by protruded region **860**. The proximal surface of large portion **815P** disposed upstream of actuator assembly **160** provides flow modification for outer surface **805** of the uppermost disk in a disk drive similar to the flow modification provided by baffle integrated comb **310** or fixture integrated comb **720**. For some embodiments, the distance between the proximal surface of large portion **815P** and outer surface **805** is less than approximately 0.8 millimeters.

Some other embodiments of the invention according to this aspect include base plates having elements with depressed regions or protruded regions as described above for the cover plates. The depressed region of base plate elements analogous to depressed contour cover plate **810**, and the large P-cover portions of base plates elements analogous to protruded contour cover plate **850** provide flow modification for outer surface **805** of the lowermost disk in a disk drive. Finally, still other embodiments have both a contoured cover plate and a contoured base plate element as described above. These contoured enclosure elements can be used with baffle integrated combs **310** or fixture integrated combs **720** as described above.

Enclosure Attached Combs

Another aspect of the invention provides a enclosure attached comb disk drive assembly comprising a spindle **170**, at least one data storage disk **110**, conventional slider assemblies **130**, an actuator assembly **160**, an enclosure attached comb **910**, an enclosure element, and attachment elements **930**. Disk **110** has an outer radial edge, an outer surface, an inner radial edge, and an inner surface. Each slider assembly **130** includes at least one transducer head capable of reading and writing information on an adjacent disk **110**. The enclosure element can be either a cover plate **910**, or an element of a base plate including an attachment surface **940**. The enclosure element has an interior surface proximal to attachment elements **930**.

What is claimed is:

1. A disk drive assembly comprising:

a spindle adapted to rotate about a longitudinal axis;

data storage disks surrounded by fluid medium, each of the disks having a disk outer edge and a disk inner edge, the disks being mounted on the spindle to rotate therewith about the spindle longitudinal axis, rotation of the disks in a first direction creating a flow of the fluid medium in the first direction, at least one of the disks having approximately concentric tracks disposed at different radial positions between the disk outer edge and the disk inner edge;

slider assemblies, each slider assembly including at least one transducer head capable of reading and writing information on one of the disks;

an actuator assembly for positioning the slider assemblies over the tracks;

a baffle disposed upstream of the actuator assembly, the baffle extending in a direction of the spindle longitudinal axis and having an inner surface disposed at least one millimeter outside of the outer edges of the disks; and

combs mounted on the baffle, at least one of the combs:

disposed adjacent to at least one of the disks to form a gap between the comb and a corresponding adjacent disk, the gap disposed in the direction of the spindle longitudinal axis and in a range from approximately 0.1 millimeter to approximately 20 millimeters;

extends radially inward from a comb outer edge to a comb inner edge, a portion of the comb outer edge disposed at the inner surface of the baffle;

disposed upstream of a corresponding actuator assembly;

extending in a disk circumferential direction form a leading edge to a trailing edge, the leading edge disposed upstream of the trailing edge;

extending radially inward from the baffle; and

having a thickness that increases from the leading edge to the trailing edge.

2. The disk drive assembly of claim **1**, wherein the baffle comprises a baffle plate.

3. The disk drive assembly of claim **2**, wherein the baffle plate and the combs are elements of an integral mechanical structure.

4. The disk drive assembly of claim **1** including a second set of combs extending radially inward from an outer attachment element inner surface, the outer attachment element inner surface having a diameter not less than the outer edge of the disks, each of the second set of combs:

disposed in a position adjacent at least one of the disks in the direction of the spindle longitudinal axis; and

disposed downstream of the slider assemblies.

5. The disk drive assembly of claim **1**, wherein at least one of the combs comprises more than one element, at least two of the comb elements are separated from each other by an intra-comb gap, the intra-comb gap extending radially from approximately the comb inner diameter to approximately the comb outer diameter.

6. The disk drive assembly of claim **1**, wherein at least one of the combs comprises a single integral structure.

7. The disk drive assembly of claim **1**, wherein at least one of the combs has a thickness that increases from the comb inner diameter to the comb outer diameter.

8. The disk drive assembly of claim **1**, wherein the gap between at least one of the combs and the corresponding adjacent disk is less than approximately 0.4 millimeters.

9. The disk drive assembly of claim **1**, wherein the at least one of the combs extends radially inward from the baffle more than approximately ten percent of a distance between an inner edge and the outer edge of the corresponding adjacent disk.

10. A disk drive assembly comprising:

a spindle adapted to rotate about a longitudinal axis;

data storage disks surrounded by fluid medium, each of the disks having a disk outer edge and a disk inner edge, the disks being mounted on the spindle to rotate therewith about the spindle longitudinal axis, rotation of the disks in a first direction creating a flow of the fluid medium in the first direction, at least one of the disks having approximately concentric tracks disposed at different radial positions between the disk outer edge and the disk inner edge;

slider assemblies, each slider assembly including at least one transducer head capable of reading and writing information on one of said disks;

an actuator assembly for positioning the slider assemblies over the tracks;

a comb fixture disposed apart from the actuator assembly, and having an inner surface separated by a first distance

from the outer edges of the disks, the first distance greater than approximately one millimeter;

combs coupled with and extending inwardly from the comb fixture, wherein the combs have a leading edge and a trailing edge, the leading edge being disposed upstream of the trailing edge, at least one of the combs:

disposed adjacent to a corresponding adjacent disk to provide a gap between the comb and the corresponding adjacent disk, the gap disposed in the direction of the spindle longitudinal axis and in a range from approximately 0.1 millimeters to approximately 20 millimeters;

extending circumferentially around the spindle longitudinal axis; and

having a thickness that increases from the leading edge to the trailing edge.

11. The disk drive assembly of claim **10** including a baffle disposed outside the disk outer edges and having an edge spaced closely to a segment of the disk outer edges, and wherein a first portion of the at least one comb extends radially inward beyond the outer edge of the corresponding adjacent disk, and a proximal edge of the first portion extends circumferentially towards the actuator assembly forming a gap between the proximal edge and the baffle of no less than ten millimeters.

12. The disk drive assembly of claim **10**, wherein each of the combs includes:

a first portion having an outer diameter approximately equal to the comb fixture inner surface; and

a second portion extending closer to the slider assemblies and having an outer diameter less than the comb fixture inner surface.

13. The disk drive assembly of claim **10**, wherein the gap between at least one of the combs and the corresponding adjacent disk is less than approximately 0.4 millimeters.

14. The disk drive assembly of claim **10**, wherein the at least one of the combs extends radially inward from the baffle more than approximately ten percent of a distance between an inner edge and the outer edge of the corresponding adjacent disk.

15. A comb assembly for reducing cross-track motion in a disk drive, the disk drive including at least one disk, a spindle, and at least one slider assembly, the comb assembly comprising:

at least one baffle disposed upstream of the slider assemblies, the baffle having an inner surface disposed at least one millimeter outside of outer edges of the disks; and

at least one comb mounted on the baffle, wherein each comb:

disposed adjacent to at least one of the disks to provide a gap between the comb and a corresponding adjacent disk, the gap disposed in the direction of a spindle longitudinal axis and in a range from approximately 0.1 millimeter to approximately 20 millimeters;

extends radially inward from a comb outer diameter, the comb outer diameter disposed approximately at the inner surface of the baffle;

disposed upstream of the slider assemblies;

extending in a disk circumferential direction from a leading edge to a trailing edge, the leading edge disposed upstream of the trailing edge;

having a thickness that increases from the leading edge to the trailing edge; and

extending radially inward from the baffle.

16. A disk drive assembly comprising:

a spindle adapted to rotate about a longitudinal axis;

at least one data storage disk surrounded by fluid medium, each disk having a disk outer edge and an a disk inner edge, each disk being mounted on the spindle to rotate therewith about the spindle longitudinal axis, rotation of the disks in a first direction creating a flow of the fluid medium in the first direction, at least one disk having approximately concentric tracks disposed at different radial positions between the disk outer edge and the disk inner edge;

at least one slider assembly, each slider assembly including at least one transducer head for reading and writing information from a disk;

an actuator assembly for positioning the slider assembly over the tracks, the actuator assembly including a leading edge and a trailing edge, wherein the leading edge of the actuator assembly is disposed upstream from the trailing edge of the actuator assembly;

a baffle disposed upstream of the actuator assembly, the baffle extending in a direction of the spindle longitudinal axis and having an inner surface disposed outside of the outer edges of the disks; and

combs mounted on the baffle, at least one of the combs having a leading edge and a trailing edge, wherein the leading edge of the comb is disposed upstream of the trailing edge of the comb and wherein at least one of the combs has a thickness that increases from the leading edge of the comb to the trailing edge of the comb.

17. The disk drive assembly of claim **16**, wherein the trailing edge of the comb is substantially parallel to the leading edge of the actuator assembly when the actuator assembly is positioned to read a data track near the disk inner edge.

* * * * *

APPENDIX C
RELATED PROCEEDINGS

None